0.05 $^{57}Co^{3+}$ VFC per Mab molecule after purification by HPLC. The cojugated Mab retained >90% of its original immunoreactivity by enzyme immunoassay. The tumor targeting properties of the antibody conjugate were evaluated in nude mice with human colon tumor xenografts over a period of 168 h. Excellent γ-imaging was attained, and biodistribution studies showed a steady increase of both tumor/liver (T/L) and tumor/blood (T/B) ratios with time (T/L and T/B were, respectively, 2.88 and 1.21 after 48 h, and 3.48 and 1.40 after 168 h). The results of imaging and biodistribution experiments will be presented in detail elsewhere, but they suggest that the VFC concept has great potential for tumor imaging and therapy.

Acknowledgment. We thank the National Institutes of Health for support of this research under Grants RO1-CA31753 and PO1-CA43904.

Supplementary Material Available: Tables of bond distances and angles, positional and equivalent isotropic thermal parameters, and anisotropic thermal parameters, details of the crystallographic data collection for *meso*-**4**, experimental data on the preparation of **2** and **4** and conjugation of ^{57}Co-**4** to T84.66 Mab, collection and reduction of X-ray data, and solution and refinement of the structure of *meso*-**4** (13 pages); tables of observed and calculated structure factors (16 pages). Ordering information is given on any current masthead page.

Cooperative Behavior in the Redox Activity of the 12-Heteropolymolybdenotungstates

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Received February 20, 1990

The 12-heteropolyacids (12-HPAs) of interest as solid and homogeneous solution catalysts can function as Brønsted acids and multielectron oxidants and are used extensively for production of short-chain alkenes and methacrylic acid from a variety of compounds.[1-8] Recently, Misono[5-8] and co-workers have observed that the aldehyde yield can be improved by employing a series of mixed-metal 12-HPAs, the $H_3PMo_{12-x}W_xO_{40}$ solid solutions, where x = 0–12. One of their results[7] (Figure 1a) reflects an approximately parabolic dependence of the excess yield of glutaraldehydes on the metal content (Mo and W) in the catalyst. The excess yield is the difference between the actual and expected yields, the latter weighted by mole fraction using the yield associated with the end points x = 0, 12. The functional form of this curve is very similar to the excess energy curves found for solid solutions.[9] In this communication, we provide an explanation of Figure 1a via a theoretical scheme with close links to the solid-solution problem.[9,10]

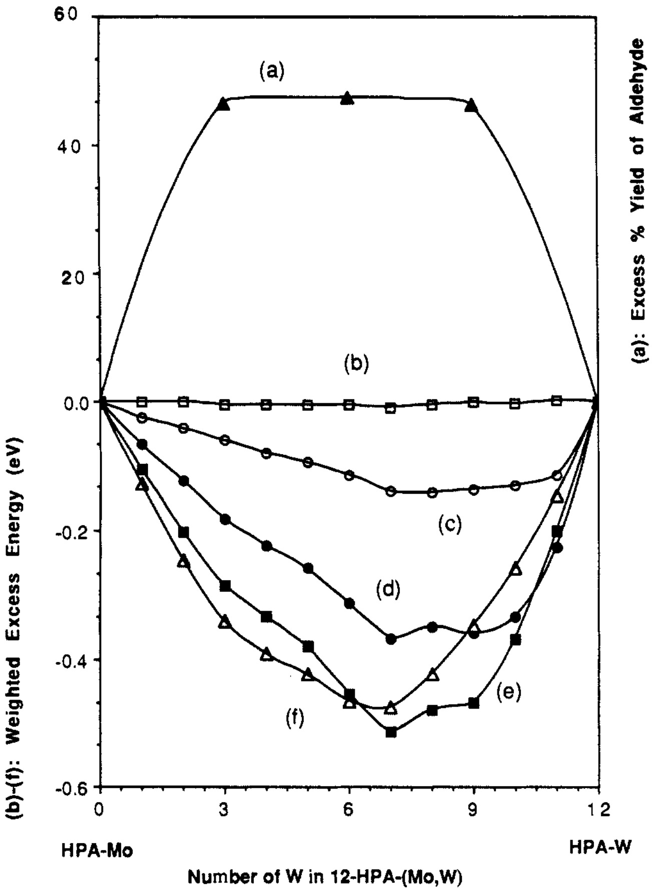

Figure 1. (a) Excess percentage yield of glutaraldehyde (Misono's result). (b–f) Computed excess energy of the 12-HPA-(Mo,W) cluster solution after the cluster has captured (b) 0, (c) 1, (d) 3, (e) 5, and (f) 12 electrons.

The heteropolyanions are of the widely known Keggin type,[3] which consists of $PM_{12}O_{40}^{n-}$ units (M = Mo, W, or V) weakly linked together. Since the redox activity of the 12-HPA-(Mo,W) solid solution takes place in the primary structure, we consider the structure of a single Keggin cluster rather than the infinite solid. We examine the entire set of $PMo_{12-x}W_xO_{40}^{3-}$ cluster solutions (x = 0–12) relying on earlier spectroscopic and structural studies[4b,11] which suggested the existence of either isomeric anions of a single composition fixed by x or solid solutions containing anions of different Mo:W ratios centered around x.[11c]

Using the EHMO method, we have evaluated the energies of all possible structures for the polyanionic clusters, $PMo_{12-x}W_xO_{40}^{3-}$ (where x = 0–12). Since previous structural studies[11,12] have indicated that the cluster dimensions are independent of their Mo/W content, we kept the structure fixed for the series. The $PMo_{12-x}W_xO_{40}^{3-}$ composition has 12 possible arrangements for x = 1 or 11 and 66 for x = 2 or 10. For x = 3–9, there is a large set of permutations. Since the Keggin cluster has a slightly distorted tetrahedral symmetry, use of an idealized structure considerably reduces the number of permutations.

If the ion $PMo_{12-x}W_xO_{40}^{3-}$ is denoted as $[Mo_{12-x}W_x]$, the excess energy of a permutation of a selected $[Mo_{12-x}W_x]$ solution is defined as

$$\Delta H_{\text{excess}}[Mo_{12-x}W_x] = H_{\text{eh}}[Mo_{12-x}W_x] - H_{\text{ideal}}[Mo_{12-x}W_x] \quad (1)$$

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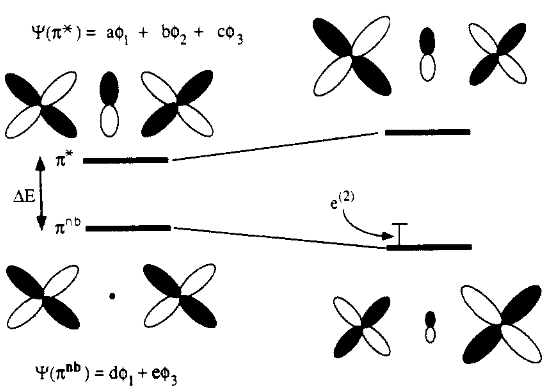

Figure 2. The second-order energy mixing associated with an asymmetric substitution in the M–O–M triatomic system (orbital mixing exaggerated for effect). ϕ_1 and ϕ_3 are the metal d orbitals, and ϕ_2 is the oxygen p orbital. $\Delta E = E_{\mathrm{MOM}}(\pi^{\mathrm{nb}}) - E_{\mathrm{MOM}}(\pi^*)$, $e^{(2)} = (c^\circ e^\circ \delta H_{ii} + c^\circ d^\circ \delta H_{ij})^2/\Delta E$, the second-order energy shift.

with $H_{\mathrm{eh}}[\mathrm{Mo}_{12-x}\mathrm{W}_x]$ being the computed enthalpy of that permutation and

$$H_{\mathrm{ideal}}[\mathrm{Mo}_{12-x}\mathrm{W}_x] = [1 - (x/12)]H_{\mathrm{eh}}[\mathrm{Mo}_{12}] - (x/12)H_{\mathrm{eh}}[\mathrm{W}_{12}] \quad (2)$$

where $H_{\mathrm{eh}}[\mathrm{Mo}_{12}]$ and $H_{\mathrm{eh}}[\mathrm{W}_{12}]$ are respectively the computed enthalpies of $\mathrm{PMo}_{12}\mathrm{O}_{40}{}^{3-}$ and $\mathrm{PW}_{12}\mathrm{O}_{40}{}^{3-}$. The weighted excess enthalpy (wt$\Delta H_{\mathrm{excess}}$) can be calculated by using the number and frequency of the permutations found for each stoichiometry.

Generally, most isostructural binary solid solutions exhibited positive excess enthalpies of mixing,[9a–e] with the exception of the (Ni,Mg)O system,[9f] for which it is negative, indicating that the formation of a solid solution is thermodynamically favorable. The wt$\Delta H_{\mathrm{excess}}$ curve of the $[\mathrm{Mo}_{12-x}\mathrm{W}_x]$ solution before reduction is found to be close to 0 (Figure 1b). As electrons enter the Keggin $[\mathrm{Mo}_{12-x}\mathrm{W}_x]$ solution cluster, the wt$\Delta H_{\mathrm{excess}}$ curves become increasingly negative (Figure 1c–f), indicating differential cluster stability. Although we should be careful in making such a comparison, this increase in stability is consistent with earlier findings[1,2,4,11] that the multielectron reduction of 12-HPA is a favorable process. However, the most striking feature of our calculations is the positive correlation between the variation in computed redox potential mimicked by wt$\Delta H_{\mathrm{excess}}$ with x and the increased yield of products found experimentally.

How does this cooperative behavior originate in electronic terms? A simple orbital argument based on second-order perturbation theory[13] may be extracted from the calculations. The orbital effect which controls the observed behavior is accessible by a study of an isolated M–O–M unit. Upon asymmetric substitution, to Mo–O–W from either W–O–W or Mo–O–Mo, the energy of the $\pi^{\mathrm{nonbonding}}$ level of the triatomic system is lowered by a second energy term $\epsilon^{(2)}$ (Figure 2) via mixing with the $\pi^{\mathrm{antibonding}}$ orbital which lies slightly higher in energy. δH_{ii} is related to the electronegativity difference between Mo and W, and δH_{ij} is the change in the metal–oxygen p interaction integral on going from Mo to W. Such mixing does not happen when the local oxygen environment is symmetrical and thus does not contribute to the computed values $H_{\mathrm{eh}}[\mathrm{Mo}_{12}]$ and $H_{\mathrm{eh}}[\mathrm{W}_{12}]$. These nonbonding levels, which are initially filled during reduction, and their energies are the factors that control the form of the computed curves of Figure 1. Such an explanation of this type of experimental behavior, we believe, is applicable to a wide variety of systems. Elsewhere[9g] we discuss a more general application of these ideas to solid solutions of extended solids.

Acknowledgment. This research was supported by NSF DMR 8819860.

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Monocyclic Enediyne Collapse to 1,4-Diyl Biradicals: A Pathway under Strain Control

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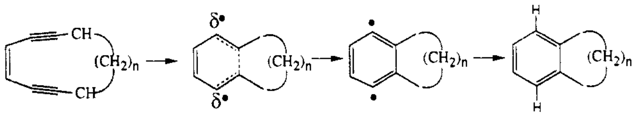
Received February 23, 1990

Over a decade ago Bergman and co-workers demonstrated elegantly that cyclic enediynes **1** cycloaromatize to give transient 1,4-diyl biradicals **3**.[1–3] More recently it has been discovered that microorganisms found in soil produce secondary metabolites in which the enediyne moiety is nested.[4–9] Presumably designed by evolutionary pressures in response to microbial war-making,[10] the natural products likewise cyclize to 1,4-diyls when properly triggered and subsequently deliver a lethal blow to competitors by cleavage of their DNA.[11–16] These observations have stirred a revival in enediyne chemistry[17–24] and stimulated studies to understand the factors controlling biradical formation.[25–29]



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