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Paradoxes and paradigms: elements and compounds – similar names, very different energetics

Part 3, cesium to radon (Cs-Rn) Z = 55–86

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Abstract

In this paper we continue to review the phonetic similarity of trivial names of chemical substances and the names of the elements in the periodic table. Thermochemical properties are explicitly considered. We review elements from cesium to radon (Cs-Rn) Z = 55–86.

Keywords Elements · Names · Compounds · Differences · Chemical Energetics

Introduction

The phonetic similarity of the sound of a trivial name of a chemical substance to the name of the element or its species can easily lead to a false idea of the actual composition or structure of a compound. In the chemical community, however, trivial and totally unsystematic names are preferred to the admittedly complicated systematic names. There often, however, is still some similarity of names but in most cases, the only common property is that these compounds are "chemicals". They often do not even share origin, e.g., "inorganic" as opposed to "organic". This seeming contradiction becomes even more apparent when thermochemical information such as the heat (or more properly enthalpy)

of formation is also considered. We note that there are over 10^8 known chemical species, and many more if one includes DNA and protein sequences and fragments. In contrast, there are calorimetrically derived thermochemical data for not many more than 10^4 , and certainly less than 10^5 , species. The extremely challenging demand for careful measurements on highly pure samples has resulted in very few contemporary laboratories whose goal and activity are to measure and understand these quantities. Relatedly and admittedly, one of the most important research activities of the authors has been the understanding, but never the measurement, of the quantities that arise from these studies.

In the present study in *Structural Chemistry*, we continue our efforts to find a compound with a subjective phonetic sound similarity for each element of the periodic table. In the first part [1] (of four parts), we discussed the elements from hydrogen (H) to argon (Ar) (Z = 1 to 18). In the second part (of four parts), we discussed the elements from potassium (K) to xenon (Xe) (Z = 19 to 54) [2]. In the current Part 3 of this review, we discuss cesium (Cs) to radon (Rn) (Z = 55 to 86). Given our interest in thermochemistry, the question arises as to how we chose which compounds to consider. In most cases, primary sources were used as reference sources for thermochemical data; however, in some cases, secondary sources, i.e., the "Domalski compendium" [3], the "Wagman et al. compendium" [4], or the "Pedley compendium" [5] were used. It is to be acknowledged that the "missing" data are quite ancient and we admit surprise at its absence in these sources. We wish to encourage the

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Table 1 Elements from cesium (Cs) to radon (Rn) ($Z = 55$ to 86) arranged according to the increasing order of atomic number accompanied with examples of compounds with ‘similarly’ sounding names but entirely different composition

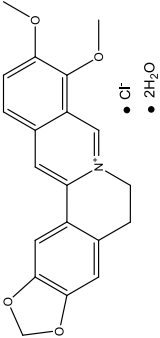
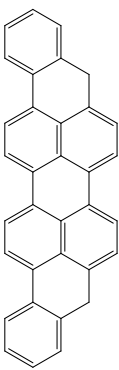
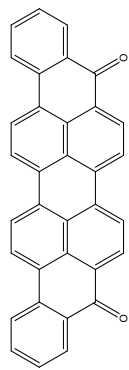
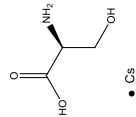
Element / Symbol / Z / compound	Molecular formula	Systematic/semisystematic name	CASRN	Energetics quantity / Reference/Comments
CESIUM, Cs, $Z = 55$ coesite	SiO_2	silicon dioxide	13778-38-6	$\Delta H_f(s) = -907(1) \text{ kJ mol}^{-1}$ [9]
BARIUM, Ba, $Z = 56$ berberine hydrochloride dihydrate	$[\text{C}_{20}\text{H}_{18}\text{NO}_4]^+\text{Cl}^- \cdot 2\text{H}_2\text{O}$	5,6-dihydro-9,10-dimethoxy-benzo[g]-1,3-benzodioxolo[5,6-a]quinolinizinium chloride dihydrate	633-65-8	$\Delta H_f(s) = -1335(1) \text{ kJ mol}^{-1}$ [10]
				
LANTHANUM, La, $Z = 57$ violanthrene; violanthrone	$\text{C}_{34}\text{H}_{20}$; $\text{C}_{34}\text{H}_{16}\text{O}_2$	5,10-dihydroanthra[9,1,2-cde]benzo[rst]pentaphene; anthra[9,1,2-cde]benzo[rst]pentaphene-5,10-dione	81-31-2; 116-71-2	$\text{p}K_a(\text{violanthrene}) = 7.3$ [11]; $\text{p}K_a(\text{violanthrone}) = 7.6$ [11]
				
				
CERIUM, Ce, $Z = 58$ serine cesium ion (1:1) complex	$\text{C}_3\text{H}_7\text{NO}_3 \cdot \text{Cs}^+$		1015696-86-2	$\Delta G(\text{two gas phase isomers of } \text{C}_3\text{H}_7\text{NO}_3 \cdot \text{Cs}^+ \text{ charged solvated and salt bridged in ca. 5:1 ratio}) \approx 3 \text{ kJ mol}^{-1}$ [12]
PRASEODYMIUM, Pr, $Z = 59$ (di)chlorine	Cl_2		7782-50-5	$\Delta H_f(g) = 0.0 \text{ kJ mol}^{-1}$ (by definition) In that “praseo” and “chlor” translate as shades of green (in classic “Greek” and dymium, like “di”, “dos” and “duo” means two, praseodymium is word-related to (di)chlorine as “the green twin”)

Table 1 (continued)


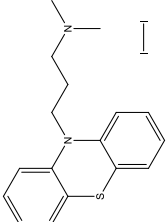
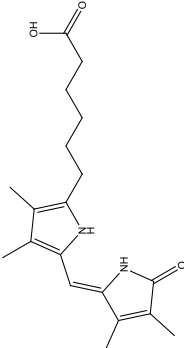
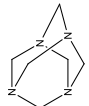
Element / Symbol / Z / compound	Molecular formula	Systematic/semisystematic name	CASRN	Energetics quantity / Reference/Comments
NEODYMIUM, Nd, Z = 60				
neopentane	C ₅ H ₁₂	2,2-dimethylpropane 	463-82-1	$\Delta H_f(l) = -190(1) \text{ kJ mol}^{-1}$ [5] $\Delta H_f(g) = -168(1) \text{ kJ mol}^{-1}$ [5]
diamond	C		7782-40-3	$\Delta H_f(s) = 2 \text{ kJ mol}^{-1}$ [13] Both neopentane and diamond have been used as reference species in the study of the energetics of compounds with quaternary carbon, $>C < [14]$
PROMETHIUM, Pr, Z = 61				
promazine	C ₁₇ H ₂₀ N ₂ S·I ₂	<i>N,N</i> -dimethyl-10 <i>H</i> -phenothiazine-10-propanamine, compd. with iodine (1:1) 	88787-14-8	For the aqueous solution phase reaction $\Delta G_{rxn}(\text{promazine}, \text{CASRN} = 58-40-2, + \text{I}_2 \rightarrow \text{promazine} \bullet \text{I}_2) = -79 \text{ kJ mol}^{-1}$ [15]
SAMARIUM, Sm, Z = 62				
[6]-semirubin	C ₁₉ H ₂₆ N ₂ O ₃	5-[(<i>Z</i>)-(1,5-dihydro-3,4-dimethyl-5-oxo-2 <i>H</i> -pyrrol-2-ylidene)methyl]-3,4-dimethyl-1 <i>H</i> -pyrrole-2-hexanoic acid 	303732-40-3	Dimerization in CHCl ₃ , $K_D \approx 25,000 \text{ M}^{-1}$ at 22 °C [16]
EUROPIUM, Eu, Z = 63				
urotropine	C ₆ H ₁₂ N ₄	1,3,5,7-tetraazaadamantane, hexamethylenetetramine 	100-97-0	$\Delta H_f(s) = 124(1) \text{ kJ mol}^{-1}$ [17] $\Delta H_f(g) = 204(1) \text{ kJ mol}^{-1}$ [17]
GADOLINIUM, Gd, Z = 64				
gallium lithium (1:2)	GaLi ₂		39343-49-2	$\Delta H_f(s) = -59(2) \text{ kJ mol}^{-1}$ [18]

Table 1 (continued)

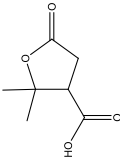
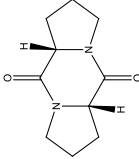
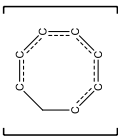
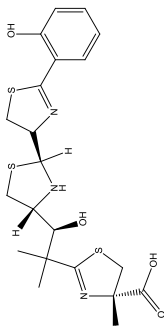
Element / Symbol / Z / compound	Molecular formula	Systematic/senisiystematic name	CASRN	Energetics quantity / Reference/Comments
TERBIUM, Tb, Z = 65 terebic acid	$C_7H_{10}O_4$	tetrahydro-2,2-dimethyl-5-oxofuran-3-carboxylic 	79-91-4	$\Delta H_f(s) = -929 \text{ kJ mol}^{-1}$ [3]
DYSPROSIUM, Dy, Z = 66 cycloproline	$C_{10}H_{14}N_2O_2$	octahydro-5H,10H-dipyrrolo[1,2-a:1',2'-d]pyrazine-5,10-dione, (5aR,10aR)-rel- 	36588-47-3	ΔG <i>trans</i> cycloproline more positive than <i>cis</i> by $> 15 \text{ kJ mol}^{-1}$ [19]
HOLMIUM, Ho, Z = 67 (mono)homotropylium ion	$[C_8H_9]^+$	cyclooctatrienylium ion 	32731-02-5	NMR studies show $\Delta G_{\text{stabilization}}$ of homoaromatic cation over the classical cyclooctatrienylium ion = 89 kJ mol^{-1} . Electrochemically, $\Delta G_{\text{redn}}(R^+ + H^+ + 2e^- \rightarrow RH)$, (homotropylium ion \rightarrow bicyclo[5.1.0]octa-2,5-diene) homotropyliene, $14 \text{ M H}_2\text{SO}_4$) = -0.92 V while that of tropylium ion, is -1.23 V [20]. We note our surprise, and indeed disappointment, that the proton affinity of cyclooctatetraene remains unreported.
ERBIUM, Er, Z = 68 yersiniabactin	$C_{21}H_{27}N_3O_4S_3$	2-[(2S)-2-[(4R)-2-[(4R)-4,5-dihydro-2-(2-hydroxyphenyl)-4-thiazolyl]-4-thiazolidinyl]-2-hydroxy-1,1-dimethylethyl]-4,5-dihydro-4-methyl-4-thiazolecarboxylic acid, (4S) 	152166-40-0	$\Delta H_f(s, 2\text{-thiazolidine-2-thione}) = 3(2) \text{ kJ mol}^{-1}$ [21] $\Delta H_f(g, 2\text{-thiazolidine-2-thione}) = 97(4) \text{ kJ mol}^{-1}$ [21]

Table 1 (continued)


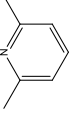
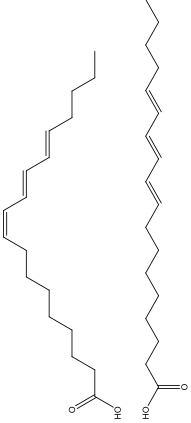
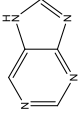
Element / Symbol / Z / compound	Molecular formula	Systematic/senisiystematic name	CASRN	Energetics quantity / Reference/Comments
THULIUM , Tm, Z = 69				
toluene	C ₇ H ₈		108-88-3	$\Delta H_f(\text{liq}) = 12(1) \text{ kJ mol}^{-1}$ [5] $\Delta H_f(\text{g}) = 50(1) \text{ kJ mol}^{-1}$ [5]
YTTERBIUM , Yb, Z = 70				
yttrium bromide	YBr ₃	yttrium (III) bromide	15923-89-4	$\Delta H_f(\text{s}) = -846(6) \text{ kJ mol}^{-1}$ [22]
LUTETIUM , Lu, Z = 71				
2,6-lutidine	C ₇ H ₉ N	2,6-dimethylpyridine 	108-48-5	Steric strain of 2,6-lutidine complex with BF ₃ = 36 kJ mol ⁻¹ [23]
HAFFNIUM , Hf, Z = 72				
hydrogen difluoride ion	[HF ₂] ⁻	bifluoride ion	18130-74-0	$\Delta H_f(\text{g})([\text{HF}_2]^-) = -713(7) \text{ kJ mol}^{-1}$ [24] Herbert H. Hyman (personal communication) told me that he found in the early days of computer searching for data in the literature, looking for information about hydrogen fluoride resulted concomitantly with information about hafnium
TANTALUM , Ta, Z = 73				
tin telluride	SnTe	tin(II) telluride	12040-02-7	$\Delta H_f(\text{s}) = -61 \text{ kJ mol}^{-1}$ [4] $\Delta H_f(\text{g}) = 161 \text{ kJ mol}^{-1}$ [4]
TUNGSTEN , W, Z = 74, as “tungsten”				
tungstand oil; α-eleostearic acid; β-eleostearic acid	C ₁₈ H ₃₀ O ₂ ; C ₁₈ H ₃₀ O ₂	9,11,13-octadecatrienoic acid, (9Z,11E,13E); 9,11,13-octadecatrienoic acid, (9E,11E,13E) 	506-23-0; 544-73-0	Heating tungstand oil resulted in rearrangement of α-eleostearic acid to form its all-trans β-isomer [25].
TUNGSTEN as “wolfram”				
wulfenite	PbMoO ₄	lead(II) molybdate	14913-82-7	$\Delta H_f(\text{s})(\text{PbMoO}_4) = -1060(2) \text{ kJ mol}^{-1}$ [26]
RHENIUM , Re, Z = 75				
purine	C ₅ H ₄ N ₄		120-73-0	$\Delta H_f(\text{s}) = 169(3) \text{ kJ mol}^{-1}$ [27]

Table 1 (continued)

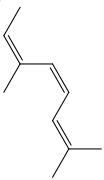
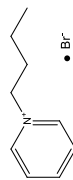
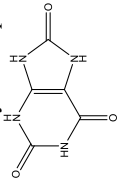

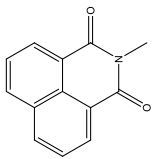
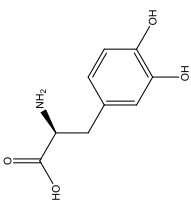
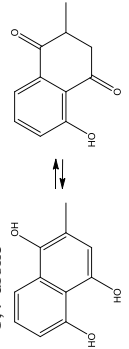
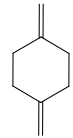
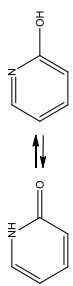
Element / Symbol / Z / compound	Molecular formula	Systematic/semisystematic name	CASRN	Energetics quantity / Reference/Comments
OSMIUM, Os, Z = 76				
<i>cis</i> -allo-ocimene	C ₁₀ H ₁₆	(4 <i>Z</i> ,6 <i>Z</i>)-2,6-dimethyl-2,4,6-octatriene 	17202-20-9	$\Delta H_f(\text{lg}) = -24(5) \text{ kJ mol}^{-1}$ [5]
IRIDIUM, Ir, Z = 77				
<i>n</i> -butylpyridinium bromide	[C ₉ H ₁₄ N] ⁺ Br [−]		874-80-6	$\Delta H_f(\text{lg}) = -165 \text{ kJ mol}^{-1}$ [28]
PLATINUM, Pt, Z = 78				
lanthanum phosphide	LaP		25275-74-5	$\Delta H_f(\text{s}) = -390 \text{ kJ mol}^{-1}$ [29]
GOLD, Au, Z = 79, as “gol”				
“fools gold” - pyrite	FeS ₂	iron(II) disulfide	1309-36-0	$\Delta H_f(\text{s}) = -174(2) \text{ kJ mol}^{-1}$ [30]
GOLD as “aurum”				
uric acid	C ₅ H ₄ N ₄ O ₃	2,5-dihydro-1 <i>H</i> -purine-2,6,8(3 <i>H</i>)-trione 	69-93-2	$\Delta H_f(\text{s}) = -619(1) \text{ kJ mol}^{-1}$ [5]
MERCURY, Hg, Z = 80				
MERCURY as “merc”				
butyl mercaptan	C ₄ H ₁₀ S	butanethiol 	109-79-5	$dH_f(\text{lg}) = -125(1) \text{ kJ mol}^{-1}$ [5] $dH_f(\text{g}) = -88(1) \text{ kJ mol}^{-1}$ [5]
MERCURY as “hydrargyrum”				
aquasilver(1+); diaquasilver(1+); triaquasilver(1+); tetraaquasilver(1+)	[AgH ₂ O] ⁺ ; [AgH ₄ O ₂] ⁺ ; [AgH ₆ O ₃] ⁺ ; [AgH ₈ O ₄] ⁺		68433-65-8; 34406-45-6; 79001-03-9; 79082-24-9	$\text{Ag}^+(\text{H}_2\text{O})_n + \text{H}_2\text{O} \rightarrow \text{Ag}^+(\text{H}_2\text{O})_{n+1}$ [31] $\Delta H_{\text{hydration}}(n=1) = 134(8) \text{ kJ mol}^{-1}$ [31]; $\Delta H_{\text{hydration}}(n=2) = 54(10) \text{ kJ mol}^{-1}$ [31]; $\Delta H_{\text{hydration}}(n=3) = 47(10) \text{ kJ mol}^{-1}$ [31]
THALLIUM, Tl, Z = 81				
<i>N</i> -methyl-1,8-naphthalimide	C ₁₃ H ₉ NO ₂	2-methyl-1 <i>H</i> -benz[<i>de</i>]isoquinoline-1,3(2 <i>H</i>)-dione 	2382-08-3	$\Delta H_f(\text{s}) = -306(4) \text{ kJ mol}^{-1}$ [32]; $\Delta H_f(\text{g}) = -196(4) \text{ kJ mol}^{-1}$ [32] Surprisingly, there are no experimentally determined measurements of the enthalpy of formation of the isoelectronic phenanone or any of its derivatives.

Table 1 (continued)

Element / Symbol / Z / compound	Molecular formula	Systematic/semisystematic name	CASRN	Energetics quantity / Reference/Comments
LEAD, Pb, Z = 82				
LEAD as»lead«				
L-DOPA	$C_9H_9NO_4$	L-3-(3,4-dihydroxyphenyl) alanine 	59-92-7	$\Delta H_f(s) = -936(8) \text{ kJ mol}^{-1}$ [33]
LEAD as»plumb«				
α -dihydroplumbagin; β -dihydroplumbagin	$C_{11}H_{10}O_3$; $C_{11}H_{10}O_3$	3-methyl 1,4,5-naphthalenetriol; 5-hydroxy-2-methyl-1,2,3,4-tetrahydronaphthalene-1,4-dione 	58274-93-4; 74413-19-7	Both forms are separately isolable, the dione tautomer is the more stable by 14 kJ mol^{-1} [34]
BISMUTH, Bi, Z = 83				
1,4-bis(methylene)cyclohexane	C_8H_{12}		4982-20-1	$\Delta H_f(g) = 64 \text{ kJ mol}^{-1}$ [35]
POLONIUM, Po, Z = 84				
“poly- <i>N</i> ”	$[N_3]^-$	azide	14343-69-2	“poly- <i>N</i> ”: azide (as a salt) is the simplest, isolable polynitrogen species, i.e., with ≥ 3 nitrogens [36].
ASTATINE, At, Z = 85				
AsTe	As = Te	arsenic monotelluride	12044*33-6	$D(\text{As} = \text{Te}) \approx 307 \text{ kJ mol}^{-1}$ [37]
RADON, Rn, Z = 86				
2-pyridone; 2-pyridinol	C_5H_5NO ; C_5H_5NO		142-08-5; 72762-00-6	$\Delta H_{f(g)}(\text{g. 2-pyridone} \rightarrow \text{2-pyridinol}) = 1(10) \text{ kJ mol}^{-1}$ [38]

remeasurement of these enthalpies of formation. Given there are many “exotic” compounds that have been recently synthesized and for which there are no measurements at all, we welcome the desired enthalpies of formation and any other thermochemical data about them.

The reader may suspect that there are alternative choices of compounds with appropriate names, and some even with the desired calorimetric measurements. Many of these compounds, for instance, are of contemporary interest to the pharmaceutical and agricultural chemistry communities. However, even with the use of “generic” names, we abstain from the use of these species and associated trivial and unsystematic names because we are loathe to “advertise” one corporation over another.

We acknowledge now our interest in etymology, but it is our view that giving the word origins for unsystematic and trivial names would be an excessive diversion of our activity. In addition, in many cases, we do not know the desired origin, nor do we know how to find it. We note a lengthy and thorough multipart recent study on the origin of the names of the elements [6–8], and while we laud this study, we do not wish to emulate it for the names of the compounds.

With the above discussion of our disclaimers as to the authors’ thermochemical interests, choice of compounds, and etymological concerns, we now refer the reader to Table 1 and conclude the current paper by beginning with Part 4 for the element francium (Fr) to oganesson (Og), $Z = 87$ to 118.

Conclusions

Compounds that have similar phonetic semi-systematic or trivial names to that of the elements have been studied in terms of their composition, structure, and chemical energetics. This review, which follows part 1, reveals even deeper differences between expected and actual composition of compounds. Nevertheless, what it is not surprising is that, semi-systematic or trivial names are widely preferred by the chemical community because of complicated nature of systematic names.

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Data availability Not applicable.

Declarations

Ethical approval We did not perform any experiments when preparing this article, so neither ethics review nor informed consent was necessary.

Consent to participate All authors agreed with participation in research and publication of the results.

Consent to publish All authors have approved the manuscript before submission, including the names and order of authors.

Competing interests All authors declare that they have no conflicts of interest.

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References

1. (a) Ponikvar-Svet M, Edwards KF, Liebman JF (2023) Paradoxes and paradigms: elements and compounds—similar names, very different energetics, Part I: hydrogen-to-argon (H-Ar) $Z = 1$ –18. *Struct Chem* 34:1205–1217. <https://doi.org/10.1007/s11224-022-02103-x>. (b) Ponikvar-Svet M, Edwards KF, Liebman JF (2023) Correction to: Paradoxes and paradigms: elements and compounds—similar names, very different energetics, Part I: hydrogen-to-argon (H-Ar) $Z = 1$ –18. *Struct Chem* 34:1219. <https://doi.org/10.1007/s11224-023-02140-0>
2. Ponikvar-Svet M, Edwards KF, Liebman JF. Paradoxes and paradigms: elements and compounds—similar names, very different energetics. Part II: potassium to xenon (K-Xe) $Z = 19$ –54. *Struct Chem* (accepted for publication). ISBN-10: 1883400015
3. Domalski ES (1972) Selected values of heats of combustion and heats of formation of organic compounds containing the elements carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. *J Phys Chem Ref Data* 1:221–277
4. Wagman DD, Evans WH, Parker VB, Schumm RH, Halow I, Bailey SM, Churney KL, Nuttall RL (1982) The NBS tables of chemical thermodynamic properties: selected values for inorganic and C1 and C2 organic substances in SI units. *J Phys Chem Ref Data* 11(Suppl 2):1–392
5. Pedley JB (1994) Thermochemical data and structures of organic compounds. TRC data series, vol 1. TRC, College Station. ISBN-13: 978-1883400019
6. Miśkowiec P (2022) Name game: the naming history of the chemical elements—part 1—from antiquity till the end of 18th century. *Found Chem*. <https://doi.org/10.1007/s10698-022-09448-5>
7. Miśkowiec P (2022) Name game: the naming history of the chemical elements: part 2—turbulent nineteenth century. *Found Chem*. <https://doi.org/10.1007/s10698-022-09451-w>
8. Miśkowiec P (2022) Name game: the naming history of the chemical elements—part 3—rivalry of scientists in the twentieth

- and twenty-first centuries. *Found Chem.* <https://doi.org/10.1007/s10698-022-09452-9>
9. Bose K, Ganguly J (1995) Quartz-coesite transition revisited: Reversed experimental determination at 500–1200 °C and retrieved thermochemical properties. *J Amer Mineral* 80:231–238. <https://doi.org/10.2138/am-1995-3-404>
 10. Cheng X, Lui Y, Hu Y, Liu Y, Li L, Di Y, Xiao X (2013) Thermal behavior and thermodynamic properties of berberine hydrochloride. *J Therm Anal Calorim* 114:1401–1407. <https://doi.org/10.1007/s10973-009-0288-9>
 11. Handa T (1955) Color reactions of condensed polycyclic aromatic hydrocarbons and related quinones in solutions of concentrated sulfuric acid. *Bull Chem Soc Jpn* 28:483–489. <https://doi.org/10.1246/bcsj.28.483>
 12. Prell JS, Chang TM, Biles JA, Berden G, Oomens J, Williams ER (2011) Isomer population analysis of gaseous ions from infrared multiple photon dissociation kinetics. *J Phys Chem A* 115:2745–2751. <https://doi.org/10.1021/jp2004166>
 13. White MA, Kahwai S, Freitas VLS, Siewert R, Weatherby JA, Verevkin SP, Ribeiro da Silva MDMC, Johnson ER, Zwaniger JW (2021) The Relative Thermodynamic Stability of Diamond and Graphite. *Angew Chem Intl Ed* 60:1546–1549. <https://doi.org/10.1002/anie.202009897>
 14. Van Vechten D, Liebman JF (1988) Number and novelty in approaches to the calculation of strainless group increments. *Isr J Chem* 21:105–110. <https://doi.org/10.1002/ijch.198100025>
 15. Saksena AR, Aradhana M (1985) Thermodynamics of molecular association of phenothiazines and iodine. 2. *J Phys Chem* 89:361–363. <https://doi.org/10.1021/j100248a035>
 16. Datta S, Lightner DA (2009) Carboxylic acid to thioamide hydrogen bonding. *Tetrahedron* 65:77–82. <https://doi.org/10.1016/j.tet.2008.09.082>
 17. Verevkin SP (2002) Relationships among strain energies of mono- and poly-cyclic cyclohexanoid molecules and strain of their component rings. *J Chem Thermodyn* 34:263–275. <https://doi.org/10.1006/jcht.2001.0896>
 18. Debski A (2017) Calorimetric Measurements of Ga-Li system by direct reaction method. *Arch Metal Matls* 62:919–926. <https://doi.org/10.1515/amm-2017-0135>
 19. Eguchi C, Kakuta A (1974) Cyclic dipeptides. I. Thermodynamics of the cis-trans isomerization of the side chains in cyclic dipeptides. *J Am Chem Soc* 96:3985–3989. <https://doi.org/10.1021/ja00819a042>
 20. Feldman M, Flythe WC (1971) Stabilities of trivalent carbon species. II. Homoaromatic and antihomoaromatic species derived from protonated cyclooctatetraene. *J Am Chem Soc* 93:1547–1549. <https://doi.org/10.1021/ja00735a065>
 21. Roux MV, Temprado M, Jiménez P, Foces-Foces C, Notario R, Parameswar AR, Demchenko AV, Chickos JS, Deakyne CA, Ludden AK, Liebman JF (2009) An experimental and theoretical study of the structures and enthalpies of formation of the synthetic reagents, 1,3-thiazolidine-2-thione and 1,3-oxazolidine-2-thione. *J Phys Chem A* 113:10772–10778. <https://doi.org/10.1021/jp9034216>
 22. Oppermann H, Ehrlich S, Hennig C (1997) Calorimetry of yttrium trihalides and yttrium oxyhalides. *Zeit Naturforsch B* 52:305–310. <https://doi.org/10.1515/znb-1997-0301>
 23. Brown HC, Gintis D, Podall H (1956) Steric effects in displacement reactions. IX. Steric strains in the reactions of 2,6-lutidine and 2,4,6-collidine with methyl iodide and with boron trifluoride. *J Am Chem Soc* 78:5375–5377. <https://doi.org/10.1021/ja01601a058>
 24. Wenthold PG, Squires RR (1995) Bond dissociation energies of F_2^- and HF_2^- . A gas-phase experimental and G2 theoretical study. *J Phys Chem* 99:2002–2005. <https://doi.org/10.1021/j100007a034>
 25. van Loon J (1953) Structure of the polymerized constituents of tung stand oil and its effect on the properties of the latter. *Verfkoniek* 26:61–63
 26. Aiswarya PM, Ganesan R, Gnanasekaran T (2018) The standard molar enthalpies of formation and heat capacities of $PbMoO_4$ (s) and Pb_2MoO_5 (s). *J Chem Thermodyn* 116:21–31. <https://doi.org/10.1016/j.jct.2017.08.011>
 27. Kirklin DR, Domalski ES (1984) Enthalpy of combustion of purine. *J Chem Thermodyn* 16:633–641. [https://doi.org/10.1016/0021-9614\(84\)90043-0](https://doi.org/10.1016/0021-9614(84)90043-0)
 28. Verevkin SP, Ralys RV, Emel'yanenko VN, Zaitsau DH, Schick C (2013) Thermochemistry of the pyridinium- and pyrrolidinium-based ionic liquids. *J Therm Anal Calorim* 112:353–358. <https://doi.org/10.1007/s10973-012-2725-4>
 29. Franzen HF, Hariharan AV (1980) The high-temperature vaporization thermodynamics of lanthanum and yttrium monophosphides as determined by Knudsen effusion. *J Chem Thermodyn* 12:975–984. [https://doi.org/10.1016/0021-9614\(80\)90138-x](https://doi.org/10.1016/0021-9614(80)90138-x)
 30. Grønvold F, Westrum EF Jr (1976) Heat capacities of iron disulfides. Thermodynamics of marcasite from 5 to 700 K, pyrite from 300 to 780 K, and the transformation of marcasite to pyrite. *J Chem Thermodyn* 8:1039–1048. [https://doi.org/10.1016/0021-9614\(76\)90135-X](https://doi.org/10.1016/0021-9614(76)90135-X)
 31. Koizumi H, Larson M, Muntean F, Armentrout PB (2003) Sequential bond energies of $Ag^+(H_2O)_n$ and $Ag^+(\text{dimethyl ether})_n$, $n = 1-4$, determined by threshold collision-induced dissociation. *Intl J Mass Spectrometry* 228:221–235. [https://doi.org/10.1016/S1387-3806\(03\)00211-2](https://doi.org/10.1016/S1387-3806(03)00211-2)
 32. Roux MV, Jiménez P, Dávalos JZ, Martín-Luengo MA, Rotello VM, Cuello AO, Liebman JF (2000) The plausible aromaticity of 1,8-naphthalimides: the enthalpy of formation of *N*-methyl-1,8-naphthalimide. *Struct Chem* 11:1–7. <https://doi.org/10.1023/A:1009222404091>
 33. Di YY, Yang WW, Kong YX, Shi Q, Tan ZC (2008) L-3-(3,4-dihydroxyphenyl) alanine low-temperature heat capacities and standard molar enthalpy of formation of l-3-(3,4-dihydroxyphenyl) alanine ($C_9H_{11}NO_4$). *J Chem Eng Data* 53:900–904. <https://doi.org/10.1021/je700644s>
 34. Reviriego F, Alkorta I, Elguero J (2008) Desmotropy in reduced plumbagins: α - and β -dihydroplumbagins. *J Mol Struct* 891:325–328. <https://doi.org/10.1016/j.molstruc.2008.04.002>
 35. von Eggers DW, Troise CA (1985) Bicyclic, boatlike cope rearrangements. Probe for conformational reference by the nodal carbon atoms. *J Am Chem Soc* 107:5739–5745. <https://doi.org/10.1021/ja00306a023>
 36. Klapötke TM, Deakyne CA, Liebman JF (2011) Paradigms and paradoxes: why is the electron affinity of the azide radical, N_3 , so large? *Struct Chem* 22:189–191. <https://doi.org/10.1007/s11224-010-9708-5>
 37. Alikhanyan AS, Steblevskii AV, Gorgoraki VI, Pashinkin AS, Malyusov VA (1986) Characteristics of evaporation of arsenic-tellurium vitreous alloys. Heats of formation of gaseous arsenic tellurides. *Dokl Akad Nauk SSSR* 288:650–654
 38. Beak P, Fry FS Jr, Lee J, Steele F (1976) Equilibration studies. Protomeric equilibria of 2- and 4-hydroxypyridines, 2- and 4-hydroxypyridines, 2- and 4-mercaptopyridines, and structurally related compounds in the gas phase. *J Am Chem Soc* 98:171–179. <https://doi.org/10.1021/ja00417a027>