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A Forensic Look at Chelated Minerals

April 14, 2026

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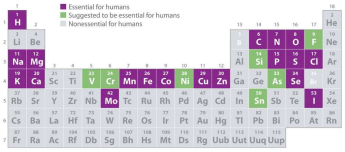
Periodic Table

- There are currently 118 elements that are discovered.
- Twenty five elements are considered necessary to the processes of life.
- Of the 25 elements necessary for life, carbon, nitrogen, oxygen, and hydrogen are approximately 95% of life composition.
- Life cannot synthesize metals: they must come from feeding or the diet



Minerals are essential components of life

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Mineral classifications

Inorganic minerals
- Consist of a cation charge balanced with an anion
- Anion typically does not have carbon as an element.
- Typically these are considered salts
- Examples include sulfate, oxides, hydroxides, phosphate, carbonates (exception to the carbon generality), and Hydroxy chlorides

Organic minerals
- Consist of cation balanced with an anion, but anion is typically much larger
- Anion includes carbon as major component of the molecule.
- These can be salts, complexes or chelates.
- Examples include acetates, citrates, propionates, amino acid complexes/chelates, proteinates.

Inorganic vs Organic

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What is an Antagonist?

- Antagonists affect the absorption of the mineral into the enterocyte. Once absorbed into the enterocyte, the mineral is subject to normal regulatory pathways and is bioavailable.

- Antagonists can be other minerals or organic compounds in the diet
- Excess intake of a single element can decrease the intestinal absorption of another element.
- Other dietary ingredients can bind up the mineral and prevent absorption
- They are present not only in animal diets, but in our diets and even in the growing of crops.
- Chelates are one of the best forms of OTM to minimize the effects of antagonists.

Antagonists are common in all nutrition

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Organic Trace Minerals Approved by AAFCO

- 57.150 – Metal Amino Acid Complex
  - Zinpro Availamins
- 57.151 – Metal (Specific amino acid) Complex
  - Zinpro methionates
  - Some glycinates such as Traxmins
- 57.142 – Metal Amino Acid Chelate
  - Balchem KeyShure Plus
- 57.28 – Metal Methionine Hydroxy Analogue Chelate
  - Mintrex products
- 57.29 – Metal Polysaccharide Complex
  - Qualitech products
- 57.23 – Metal Proteinate
  - Balchem KeyShure, Trouw, JH Biotech, Buffermin, and others.

General forms of OTM approved for use in feeds

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What is a Chelate?

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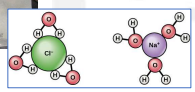
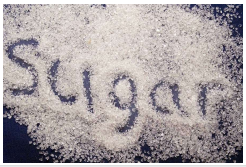
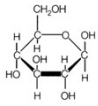
Types of Binding

- Physical binding (slow release)
- Chemical binding
  - Ionic
  - Covalent
  - Coordination







Chelates and complexes have covalent and coordination bonding

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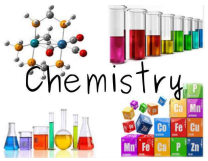
Chemical Requirements for Metal Chelation

- The ligand must contain two atoms that can bond to the same metal.
- The ligand must form a heterocyclic ring with the metal as the closing member.
- Must have a metal:ligand molar ratio that is a minimum of 1:1.



Chelation is a chemical reaction

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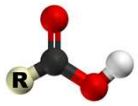
1. Ligand Must Contain Two Atoms That Can Bind to the Same Metal

- Atoms can be single or part of a functional moiety.
- Must donate one or both electrons to the metal-ligand covalent bond.
- Examples of atoms can be N, O, S or P.
- Examples of functional moieties could be carboxylic, carbonyls, amino, sulfhydryls, or phosphates.



Bidentate binding is key

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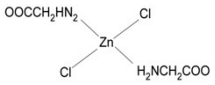
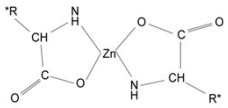
2. Ligand Must Form a Heterocyclic Ring With the Metal As the Closing Member

- If it does not form a ring then it is a complex.



- If the ligand is bidentate, then it is capable to form a ring.



Rectangle

Square (unique form of a rectangle)

Ring structure is a defining characteristic

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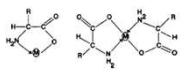
3. Must Have a Ligand:Metal Molar Ratio that is a Minimal 1:1

- This necessitates knowing the molecular weight and moles of the ligand.
- Since chelation is a reaction, it must be chemically balanced.
- If it is less than a 1:1 ratio, it cannot be fully chelated.



Molar ratios are usually the least understood requirement

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Why Are Molar Ratios Important?

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Absolute Limits

- Chemistry is governed by laws that impose absolute limits.
- A molecular formulation can provide information on these limits.
- A lot of forensic information can be deduced from product specifications based upon these chemistry limits.

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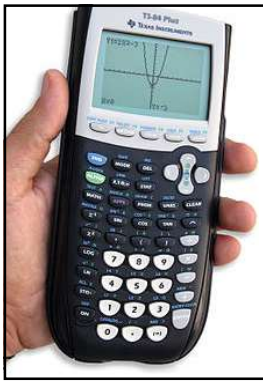

Zinc and Glycine Example of Absolute Limits

- Glycine:Zn molar ratio of 1:1
  - $Zn(NH_2CH_2COO)$
  - Absolute limit of Zn is molecular weight of Zn over the molecular weight of the compound.
  - 65.3/(65.3+74.1) = 0.468 or 46.8%
- Glycine:Zn molar ratio of 2:1
  - $Zn(NH_2CH_2COO)_2$
  - 65.3/(65.3+74.1+74.1) = .306 or 30.6%

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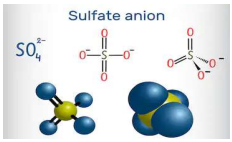
It's All About the Anion!

- In agricultural products, pure metal sources are not typically used.
- Organic trace minerals use those same inorganic salts to create the organic trace mineral.
- Those anions are still present in the product and are not purified out.
- These anions take up mass, or space, in th formulations.
- Examples are sulfates, chlorides, and carbonates



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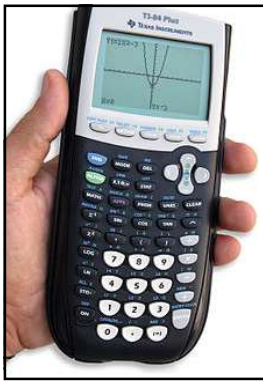

Zinc and Glycine Example of Absolute Limits (Revisited)

- **Glycine:Zn Sulfate molar ratio of 1:1**
  - **$Zn(NH_2CH_2COO)HSO_4$**
  - **65.3/(65.3+74.1+97.1) = 0.276 or 27.6%**
- Upper absolute limit decreased from 46.8% to 27.6% due to sulfate anion.
- Any waters of hydration with the mineral source (copper sulfate pentahydrate) can decrease it even more.

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A Tale of Two Glycinates

Results of chemical analysis

- Copper glycinate sample from India

Analyte	Result %	Moles/100 g
Copper	25.55	0.402
Nitrogen	1.12	0.08
Sulfur	12.32	
Moisture	17.39	

- Sulfur value confirms that copper sulfate was the source of copper.
- High level of moisture suggest that the waters of hydration have not been removed.
- Not enough glycine
- Product is not a copper glycinate

- Zinc glycinate sample from EU.

Analyte	Result %	Moles/100 g
Zinc	27.00	0.414
Nitrogen	5.90	0.421
Calcium	11.48	
Moisture	4.16	

- There is sufficient glycine for the zinc present.
- Low moisture suggests that this product may have undergone a reaction.
- High level of Calcium may indicate a calcium carbonate carrier/filler/processing aid.
- Product appears to be a zinc glycinate.

The chemistry reveals the truth

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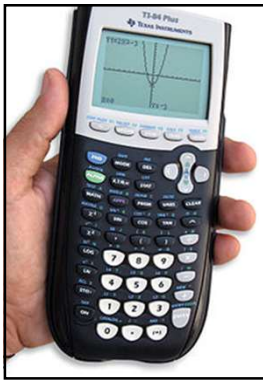

An Example of Zinc Sulfate and Protein Hydrolysate Absolute Limits

- The process is essentially the same as with a single ligand.
- The average molecular weight of the amino acids must be determined.
- Hydrolysate:Zn Sulfate molar ratio of 1:1
  - $Zn(NH_2CHR^*COO)HSO_4$
    - *R – any amino acid side chain
  - 65.3/(65.3+150+97.1) = 0.209 or 20.9%
- For analysis purposes, nitrogen (crude protein) can be used to determine moles of protein hydrolysate.

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Analysis of a metal proteinate

- Sample of a zinc proteinate was analyzed
- AAFCO definition of a metal proteinate states that it must be chelated.

Analyte	Result %	Moles per 100 g
Zinc	27.72	0.425
Nitrogen	1.917	0.137
Sulfur	12.40	
Moisture	1.76	

- Zinc source was zinc sulfate.
- There is not sufficient protein for the zinc to be chelated, and it does not meet the AAFCO definition.

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What if I Don't have Access to an Analytical Lab?

Get out your calculator

- Product documentation can provide a wealth of information
- Product data sheets, SDS sheets, or even certificate of analysis sheets are great sources.
- Typically, need the mineral percentages and the amount of ligand (typically crude protein)
- Look for other information that would indicate specific ligands or classifications.
- Documentation that does not provide sufficient information to make an informed decisions, should also make the product suspect.

Element	Molecular Weight
Zinc	65.3
Copper	63.5
Manganese	54.9
Iron	55.8
Nitrogen	14.0

Calculation	Equation
% Nitrogen	Crude Protein % / 6.25
Moles of element	% element / molecular weight
L:M ratio	Moles ligand (nitrogen)/ moles metal

Simple arithmetic

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Example of Documentation Evaluation

Look at the product specifications.

KeyShure® Chelated Minerals

Product Specification Sheet
Zinc Proteinate
IFN 6-09-897
Product Code: F3610115

A Zinc Proteinate conforming to AAFCO definition #57.23 "The product resulting from the chelation of a soluble salt, amino acids and/or partially hydrolyzed protein"

Product Specification:
Appearance - Light yellow tan to dark yellow tan speckled powder
Zinc - 15% (Min 150 mg/kg) Guaranteed minimum analysis
Moisture - ≤10.0% Guaranteed maximum analysis

Typical Properties:

Arsenic (As)	≤ 12 ppm	Crude Protein	34% (340,000 mg/kg)
Lead (Pb)	≤ 100 ppm	Mercury (Hg)	≤0.2ppm
Cadmium (Cd)	≤ 10 ppm		

Typical Properties are verified, at a minimum, annually. This product contains hydrolyzed vegetable protein. This product is free of risk for BSE/TSE; no animal products or animal byproducts are used in the manufacture of this material. Raw Materials used in the manufacture of this material must be assumed to be sourced from genetically modified (GM) materials. This product should be considered GM under the requirements defined by current EU regulations.

- 15 g zinc/100 g product = 0.230 moles of zinc per 100 g product
- 34% crude protein is 5.44% nitrogen.
- 5.44 g nitrogen/100 g product = 0.389 moles nitrogen per 100 g product
- Mole ratio of nitrogen to zinc is 1.69:1
- Sufficient to meet AAFCO definition 57.23

Simple arithmetic reveals a lot.

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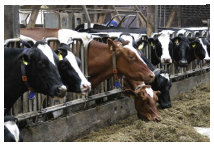
Conclusions

- Organic trace minerals are an essential, high value part of animal nutrition.
- There are many suppliers that market organic trace minerals.
- Economic dishonesty is also present in the market.
- Simple forensic analysis can provide assurance that money spent for organic trace minerals not buying an economic imitator.

KeyShure® Chelated Minerals



KeyShure Plus Amino Acid Chelated Minerals

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balchem®
Solve Today. Shape Tomorrow.

Thank You!

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