
"A" students work (without solutions manual)
~ 10 problems/night.

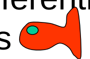
Dr. Alanah Fitch
Flanner Hall 402
508-3119
afitch@luc.edu

Office Hours Th&F 2-3:30 pm

**Module #18: Complex Ions: Saving future Mr. Litvinenkos**

## FITCH Rules

General

- G1: Suzuki is Success
- G2. Slow me down
- G3. Scientific Knowledge is Referential
- G4. Watch out for Red Herrings 
- G5. Chemists are Lazy

Chemistry

- C1. It's all about charge $E_{el} = k\left(\frac{q_1 q_2}{r_1 + r_2}\right)$
- C2. Everybody wants to "be like Mike"
- C3. Size Matters
- C4. Still Waters Run Deep  **Piranhas lurk**
- C5. Alpha Dogs eat first

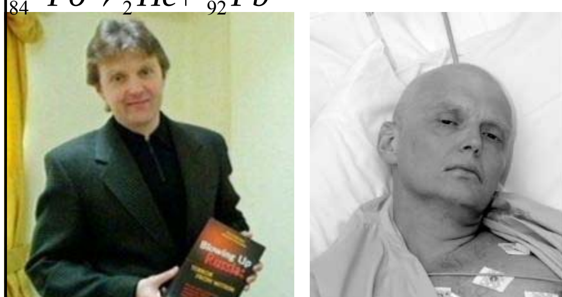
What is an alpha dog?

High charge, low volume

An Example of rate constants in the real world: context and calculations

## Toxicology of Radioactive Exposure

$^{210}_{84}Po \rightarrow {}^{4}_{2}He + {}^{206}_{92}Pb$



190 ng dose suspected

Could it be Removed using Complexation reactions?

**Alexander Litvinenko, former Russian KGB agent poisoned with Polonium on Nov. 1, died Nov. 23, 2006**

Review: Module 15: Kinetics and Biology

How and where Po might go depends upon it's chemistry

1. Same family as O, S, an Se, Te

   $Po = [Xe]6s^2 4f^{14} 5d^{10} 6p^4$

2. But with a smaller ionization energy

   $M \rightarrow M^+ + e$

2. it does not form covalent bonds
   E.N. =2.0 for Po vs. 2.55 for C and 3.44 for O

3. Forms ionic, soluble compounds

   **$PoCl_2$; $PoCl_4$, $PoBr_2$, $PoBr_4$, $PoI_2$, $PoI_4$, $PoO_2$,**

4. Atomic radii similar to
   Ga, Sb

] Review: Module 15: Kinetics and Biology ements/elements/text/Po/eneg.html


"A" students work (without solutions manual)
~ 10 problems/night.

Dr. Alanah Fitch
Flanner Hall 402
508-3119
afitch@luc.edu

Office Hours Th&F 2-3:30 pm

**Module #18: Complex Ions: Saving future Mr. Litvinenkos**

**Define a Complex Ion**

---

## Example 1: Complex ions $Cu(NH_3)_6^{2+}$

Experiment:

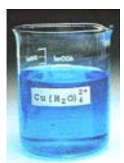
1. copper scrub brush
2. add water
3. dry
4. add ammonia

What happened (chemically)?

---

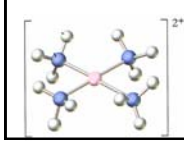
**Example 1: Metal Complex**

$$2H_2O \rightleftarrows 2OH^-_{aq} + 2H^+_{aq}$$
$$2H^+_{aq} + 2e \rightleftarrows H_{2,g}$$
$$Cu_s \rightleftarrows Cu^{2+}_{aq} + 2e$$
$$Cu^{2+}_{aq} \xrightarrow{H_2O} Cu(H_2O)^{2+}_{4,aq}$$



**Vocabulary**
**F**ormation constant

$$Cu^{2+}_{aq} + NH_{3,aq} \rightleftarrows CuNH^{2+}_{3,aq} \qquad K_{f1}$$
$$CuNH^{2+}_{3,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{2,aq} \qquad K_{f2}$$
$$Cu(NH_3)^{2+}_{2,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{3,aq} \qquad K_{f3}$$
$$Cu(NH_3)^{2+}_{3,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{4,aq} \qquad K_{f4}$$



---

**Example 1: Metal Complex**

$$2H_2O \rightleftarrows 2OH^-_{aq} + 2H^+_{aq}$$
$$2H^+_{aq} + 2e \rightleftarrows H_{2,g}$$
$$Cu_s \rightleftarrows Cu^{2+}_{aq} + 2e$$
$$Cu^{2+}_{aq} \xrightarrow{H_2O} Cu(H_2O)^{2+}_{4,aq}$$

| Reaction | Vocabulary: Formation constant | Vocabulary: Coordination Number |
|---|---|---|
| $Cu^{2+}_{aq} + NH_{3,aq} \rightleftarrows CuNH^{2+}_{3,aq}$ | $K_{f1}$ | 1 |
| $CuNH^{2+}_{3,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{2,aq}$ | $K_{f2}$ | 2 |
| $Cu(NH_3)^{2+}_{2,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{3,aq}$ | $K_{f3}$ | 3 |
| $Cu(NH_3)^{2+}_{3,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{4,aq}$ | $K_{f4}$ | 4 |

$$Cu_s + 4NH_{3,aq} + 2H_2O \rightleftarrows Cu(NH_3)^{2+}_{6,aq} + 2H_{2,g}$$

Can this be considered as an Acid/Base Rx?

$$H_2O + :NH_3 \rightleftarrows HNH_3 + OH^-$$

N is a Lewis:
Base (**Electron pair donor)**

$$H_2O \rightleftarrows H^+ + :\ddot{O}H^-$$

$$Al^{3+} + :\ddot{O}H^- \rightleftarrows Al(OH)^{2+}$$

$$H_2O + Al^{3+} \rightleftarrows Al(OH)^{2+} + H^+$$

O is a Lewis Base
(**Electron pair donor)**

$Al^{3+}$ is a Lewis:
Acid (**Electron pair acceptor)**


"A" students work
(without solutions manual)
~ 10 problems/night.


Dr. Alanah Fitch
Flanner Hall 402
508-3119
afitch@luc.edu


Office Hours Th&F 2-3:30 pm

**Module #18:**
**Complex Ions:**
**Saving future**
**Mr. Litvinenkos**

**Types of Ligands**

**Ligand** from Latin *ligare* "to bind"

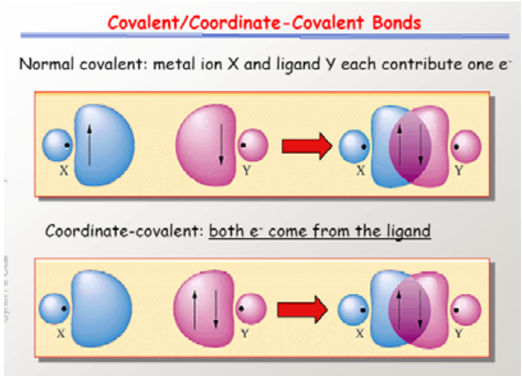
"a molecule or anion with an unshared pair of electrons donating a lone pair to a metal cation to form a coordinate covalent bond"

Elements with unshared pairs of electrons capable of being ligands:
C, N, O, S, F. Cl, Br, I

Molecules acting as ligands:
$:NH_3$; $:OH_2$

Ions acting as ligands:
$Cl^-$, $Br^-$, $I^-$, $[:C\equiv N:]^-$

http://chem.chem.rochester.edu/~chemlab2/Lecture%203%202-12-07%20Fe-oxalate%20synthesis.pdf



## **Example 2:** A complex formed from a ligand and a metal

$Pb^{2+}_{aq} + Cl^-_{aq} \rightleftarrows PbCl^+_{aq}$ $\quad K_{f1} \quad K_{f1} = \frac{[PbCl^+_{aq}]}{[Pb^{2+}_{aq}][Cl^-_{aq}]}$ $\quad [PbCl^+_{aq}] = K_{f1}[Pb^{2+}_{aq}][Cl^-_{aq}]$

$PbCl^+_{aq} + Cl^-_{aw} \rightleftarrows PbCl^0_{2,aq}$ $\quad K_{f2} \quad K_{f2} = \frac{[PbCl^0_{2,aq}]}{[PbCl^+_{aq}][Cl^-_{aq}]};$ $\quad [PbCl^0_{2,aq}] = K_{f2}[PbCl^+_{aq}][Cl^-_{aq}]$

$[PbCl^0_{2,aq}] = K_{f2}K_{f1}[Pb^{2+}_{aq}][Cl^-_{aq}][Cl^-_{aq}]$

$PbCl^0_{2,aq} + Cl^-_{aq} \rightleftarrows PbCl^-_{3,aq}$ $\quad K_{f3} \quad K_{f3} = \frac{[PbCl^-_{3,aq}]}{[PbCl^0_{2,aq}][Cl^-_{aq}]};$ $\quad [PbCl^-_{3,aq}] = K_{f3}[PbCl^0_{2,aq}][Cl^-_{aq}]$

$[PbCl^-_{3,aq}] = K_{f1}K_{f2}K_{f3}[Pb^{2+}_{aq}][Cl^-_{aq}][Cl^-_{aq}][Cl^-_{aq}]$

$PbCl^-_{3,aq} + Cl^-_{aq} \rightleftarrows PbCl^{2-}_{4,aq}$ $\quad K_{f4}$

Don't sweat the math =an example only

$[PbCl^{2-}_{4,aq}] = K_{f1}K_{f2}K_{f3}K_{f4}[Pb^{2+}_{aq}][Cl^-_{aq}][Cl^-_{aq}][Cl^-_{aq}][Cl^-_{aq}]$

## Example 2: A complex formed from a ligand and a metal

$[PbCl^+_{aq}] = K_{f1}[Pb^{2+}_{aq}][Cl^-_{aq}]$

$[PbCl^0_{2,aq}] = K_{f2}K_{f1}[Pb^{2+}_{aq}][Cl^-_{aq}][Cl^-_{aq}]$

$[PbCl^-_{3,aq}] = K_{f1}K_{f2}K_{f3}[Pb^{2+}_{aq}][Cl^-_{aq}][Cl^-_{aq}][Cl^-_{aq}]$

$[PbCl^{2-}_{4,aq}] = K_{f1}K_{f2}K_{f3}K_{f4}[Pb^{2+}_{aq}][Cl^-_{aq}][Cl^-_{aq}][Cl^-_{aq}][Cl^-_{aq}]$

$$\alpha_o \equiv \frac{[Pb^{2+}_{aq}]}{[Pb_{aq,all\ forms}]}$$

$$[Pb_{aq,all\ forms}] = [Pb^{2+}_{aq}] + [PbCl^+_{aq}] + [PbCl^0_{2,aq}] + [PbCl^-_{3,aq}] + [PbCl^{2-}_{4,aq}]$$

$$[Pb_{aq,allforms}] = [Pb^{2+}_{aq}] + K_{f1}[Pb^{2+}_{aq}][Cl^-_{aq}] + K_{f1}K_{f2}[Pb^{2+}_{aq}][Cl^-_{aq}]^2 + K_{f1}K_{f2}K_{f3}[Pb^{2+}_{aq}][Cl^-_{aq}]^3 + K_{f1}K_{f2}K_{f3}K_{f4}[Pb$$

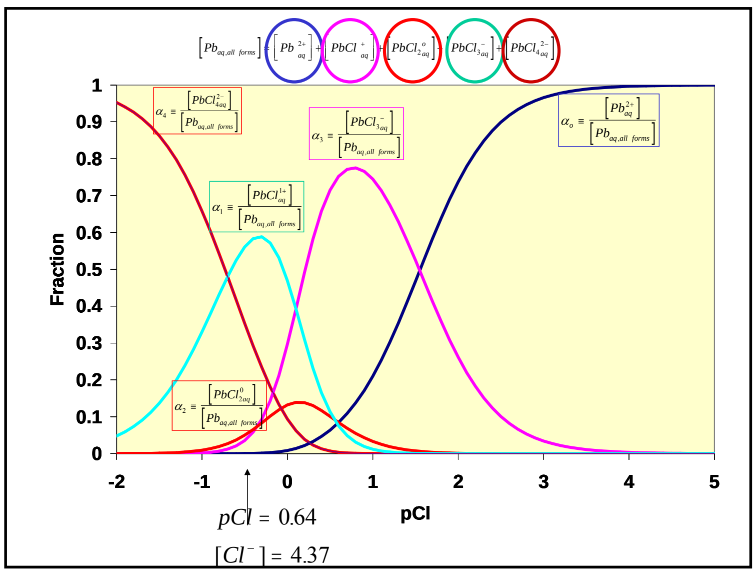
$$[Pb_{aq,allforms}] = [Pb^{2+}_{aq}]\left(1 + K_{f1}[Cl^-_{aq}] + K_{f1}K_{f2}[Cl^-_{aq}]^2 + K_{f1}K_{f2}K_{f3}[Cl^-_{aq}]^3 + K_{f1}K_{f2}K_{f3}K_{f4}[Cl^-_{aq}]^4\right)$$

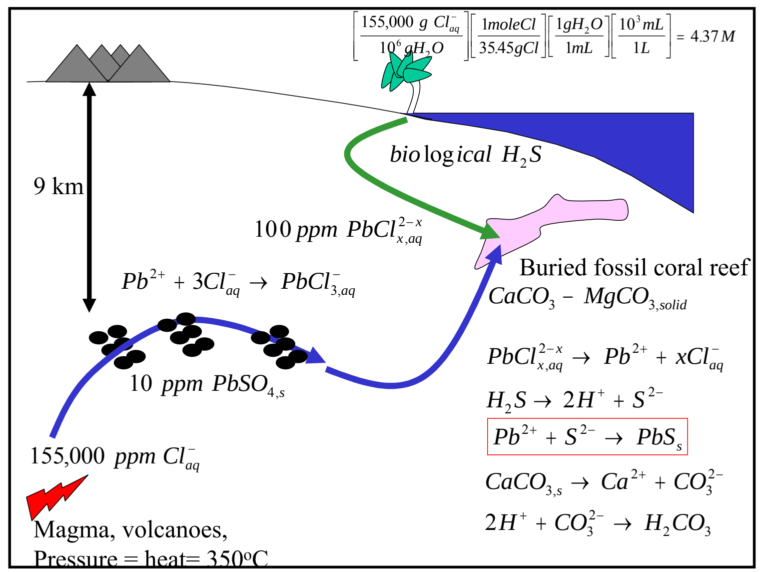
$$\alpha_0 = \frac{[Pb^{2+}_{aq}]}{[Pb_{aq,allforms}]} = \frac{[Pb^{2+}_{aq}]}{[Pb^{2+}_{aq}]\left(1 + K_{f1}[Cl^-_{aq}] + K_{f1}K_{f2}[Cl^-_{aq}]^2 + K_{f1}K_{f2}K_{f3}[Cl^-_{aq}]^3 + K_{f1}K_{f2}K_{f3}K_{f4}[Cl^-_{aq}]^4\right)}$$

$$\alpha_0 = \frac{[Pb^{2+}_{aq}]}{[Pb_{aq,allforms}]} = \frac{1}{\left(1 + K_{f1}[Cl^-_{aq}] + K_{f1}K_{f2}[Cl^-_{aq}]^2 + K_{f1}K_{f2}K_{f3}[Cl^-_{aq}]^3 + K_{f1}K_{f2}K_{f3}K_{f4}[Cl^-_{aq}]^4\right)}$$

Predicts amt of total Pb as $Pb^{2+}$ based only on [Cl-]

Same for $\alpha_1, \alpha_2, \alpha_3, \alpha_4$



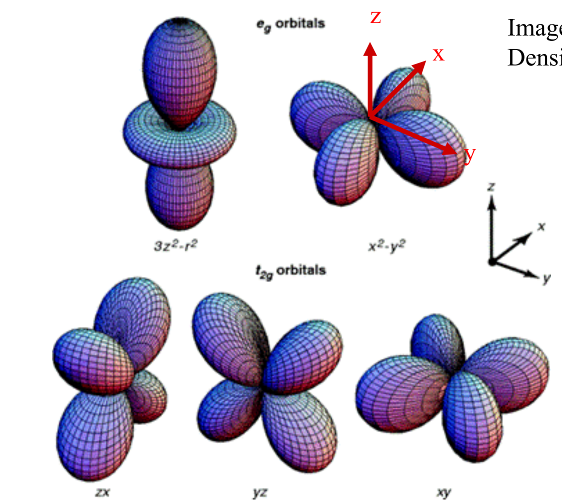
Who is the central atom?

Mostly: $Cr$, $Mn$, $Fe^{2+}$, $Fe^{3+}$, $Co^{2+}$ $Co^{3+}$, $Ni^{2+}$, $Cu^{+}$, $Cu^{2+}$, $Zn^{2+}$ $Ag^{+}$

To a lesser extent $Al^{3+}$, $Sn^{2+}$, $Hg^{2+}$, $Pb^{2+}$

All of these have accessible d orbitals!

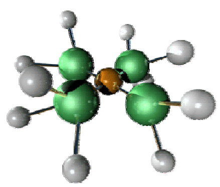
Images of electron Density of d orbitals

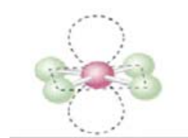



http://vinobalan.tripod.com/sitebuildercontent/sitebuilderpictures/picture1.gif

Consider the square planar complex,

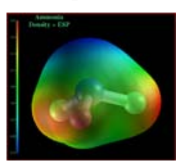
$Cu(NH_3)_4$





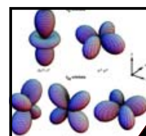
http://www.uel.education.fr/consultation/reference/chimie/elementsp1/apprendre/gcb.elp.fa.101.a2/content/images/cu(nh3)4.gif

formed from the ability of four incoming electron pairs on $NH_3$

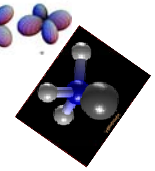


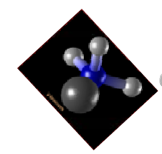
To get very close to the positive nucleus of Cu

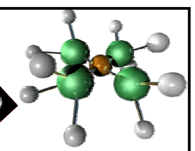
Keep in mind Rule C1: It's All about Charge!

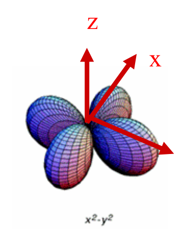


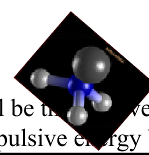
$$E_{el} = k\left(\frac{q_1 q_2}{r_1 + r_2}\right)$$



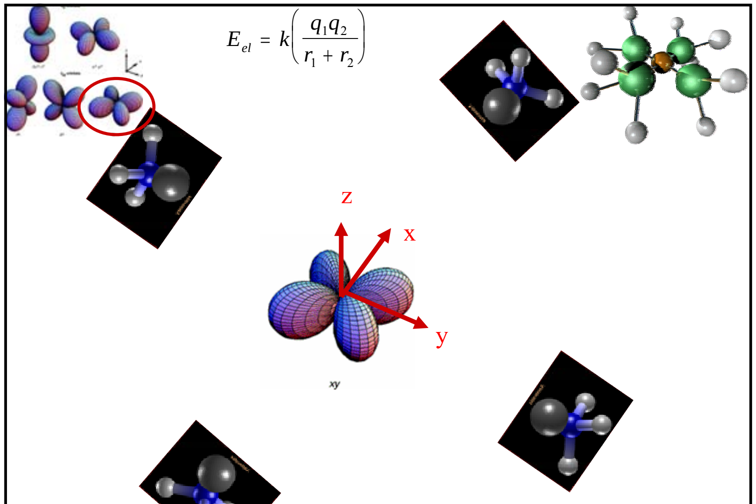






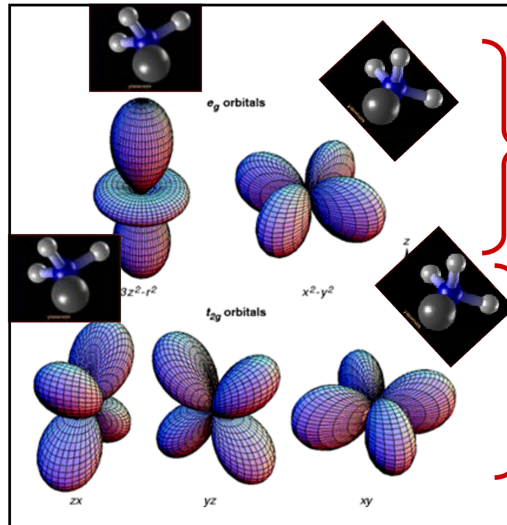



What will be th[...]ve attractive energy between :N and + nucleus
Vs the repulsive e[...]rgy between :N and d electrons in the $x^2-y^2$ orbitals?




$$E_{el} = k\left(\frac{q_1 q_2}{r_1 + r_2}\right)$$

What will be the attractive energy between :N and + nucleus
Vs the repulsive energy between :N and d electrons in the **xy** orbitals?




http://vinobalan.tripod.com/sitebuildercontent/sitebuilderpictures/picture1.gif

Major repulsion
:N with d electrons

Less repulsion
:N with d electrons

Sets the kinds number
Of ligands that can
Orient thems

Who is the central atom?

6 6 4 6 6 2 4 4

Mostly: Cr, Mn, $Fe^{2+}$, $Fe^{3+}$, $Co^{2+}$ $Co^{3+}$, $Ni^{2+}$, $Cu^{+}$, $Cu^{2+}$, $Zn^{2+}$

$Ag^{+}$

Typical CN 2

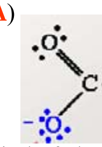
To a lesser extent $Al^{3+}$, $Sn^{2+}$, $Hg^{2+}$, $Pb^{2+}$

4 2

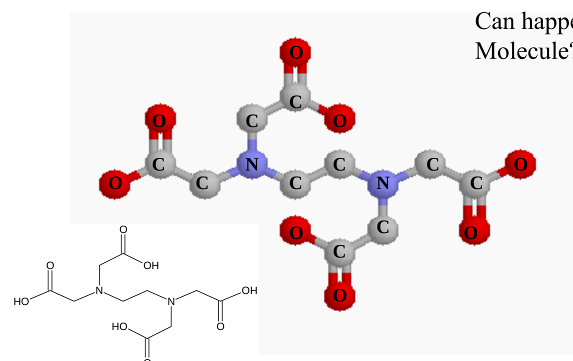
**Example 3**: **E**thylene**d**iamine**t**etra**a**cetic acid (**EDTA**)

Another type of Ligand has both

a. Electron pairs (N:)
b. net charge (COO-) And electron pair on O




What kind of chemistry
Can happen with this
Molecule?




Note: structure
Omits hydrogens
Rule G5:
Chemists are lazy

Vocabulary Rules for Coordination Chemistry

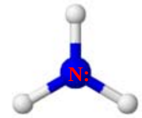
1. Central Atom = cation = Lewis acid
2. Ligands = Lewis Bases
3. Lewis bases have an electron pair which "bites" the metal
   a. 1 electron pair = mono**dentate**
   b. 2 electron pair = bi**dentate**
   c. > 2 electron pair = poly**dentate**


**Chelate** from Latin from Greek *khele* "claw"

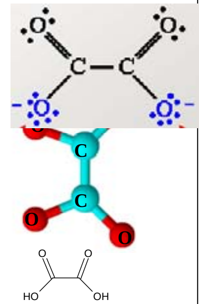
molecular ligand with more than one bond with central metal atom.

---

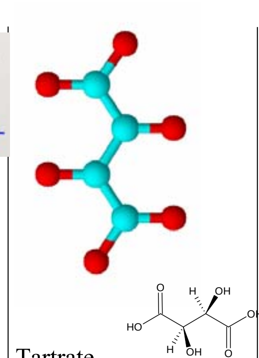
How Many Teeth on the Following Ligands (Lewis Bases)?



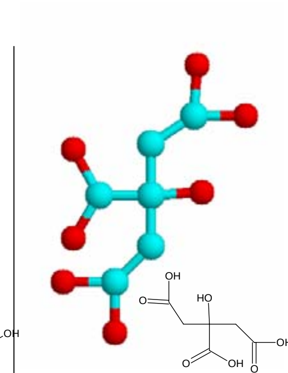

ammonia




oxalate
Rhubarb leaves
From Latin: *oxalis* :wood Sorrel; From Greek *oxus*, sour




Tartrate
Crystallized wine
From Greek: *tartaron*




citrate
lemons
From Latin: *citron* tree

---

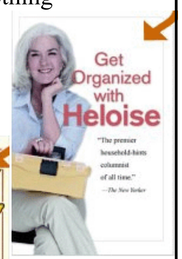
**Example 4**: Rust:

$$Fe_s + 3\left[:\ddot{O}H^-\right] \rightleftarrows Fe(OH)_{3,s} + 3e$$

a red stain on clothing

To remove:
- add lemon juice (citric acid)
- add cream of tartar (tartric acid)
- add oxalic acid

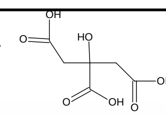
Which will work better:
oxalic acid or citric acid?



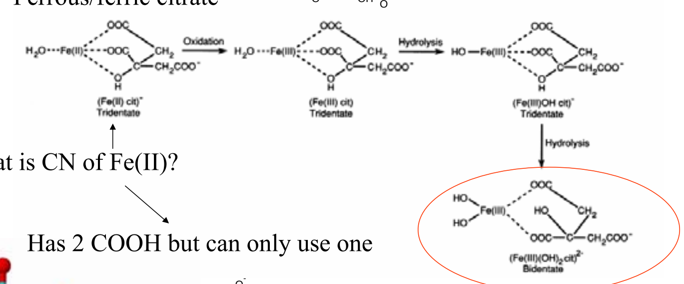


---

http://aem.asm.org/cgi/reprint/59/1/109.pdf




Ferrous/ferric citrate

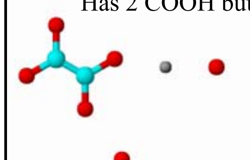


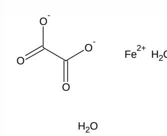

What is CN of Fe(II)?

Has 2 COOH but can only use one

Uses 2 COOH

What is CN of Fe(III)?



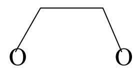



Ferrous/ferric oxalate
http://www.chemexper.com/index.shtml?main=http://www.chemexper.com/search/cas/516-03-0.html

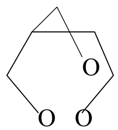
Which of Eloise's hints works better? Oxalic acid or citric acid?

1. Both bites are electron pairs on oxygen
- Compare $K_f$ (formation constants)
- What do you observe?
- How do you explain it?

6. citrate can wrap around $Fe^{2+}$ better.



oxalate



citrate

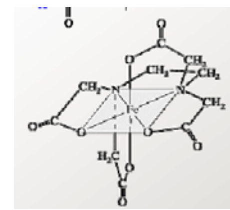
| | $\log K_f$ | |
|---|---|---|
| metal | oxalate | citrate |
| $Mg^{2+}$ | 2.8 | 3.2 |
| $Ca^{2+}$ | 3.0 | 3.2 |
| $Fe^{2+}$ | 7.5 | 11.8 |
| $Cu^{2+}$ | 6.2 | 14.2 |

Conclusion: **flexibility** is good.

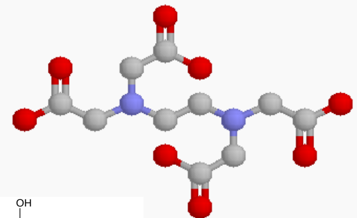
---

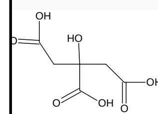
How many bites?

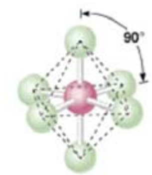
What possible shape with iron?



Ethylenediaminetetraacetic acid






$AX_6$: octahedron



---

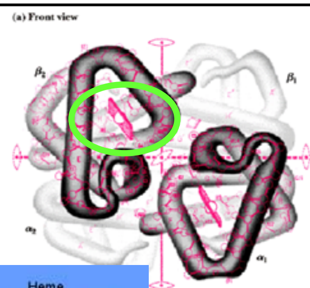
**Example 5:**

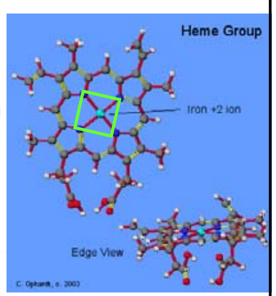
Hemeglobin:

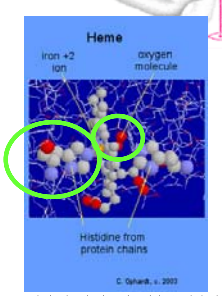
Oxygen carrier

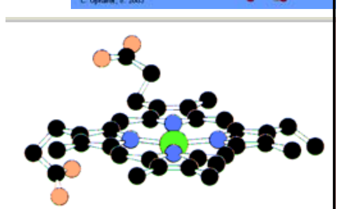
Fe is square planar with 2 more coordination sites top and bottom.

One is used for oxygen transport



http://www.elmhurst.edu/~chm/vchembook/568globularprotein.html

---

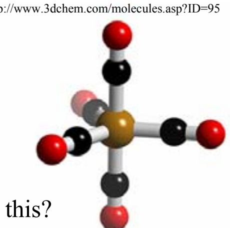
Structure of complex is important

http://www.3dchem.com/molecules.asp?ID=95

How hemoglobin works (sort of)

$Fe^{2+}$ can have C.N. = 5

Example: $Fe(CO)_5$



What shape is this?

(Triangular bipyramid)

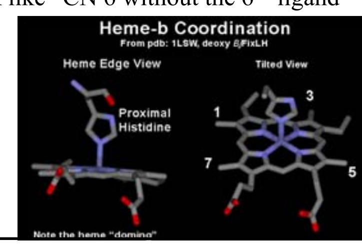
In deoxygenated hemoglobin it has CN 5, but it is forced

By the shape of the protein to "look like" CN 6 without the 6th ligand

This means that it accepts the 6th Ligand ($O_2$) (carries oxygen)

But not so strongly. It can easily release it again because it isn't really fully designed to be 6 CN

doming




http://www.wsu.edu/~hemeteam/tutorials.html#B

*The British Journal of Radiology*, 70 (1997), 859–861 © 1997 The British Institute of Radiology

Case report

**MRI findings of VIIth cranial nerve involvement in sarcoidosis**

M OKI, MD, S TAKIZAWA, MD, PhD, Y OHNUKI, MD and Y SHINOHARA, MD, PhD

Department of Neurology, Tokai University School of Medicine, Bohseidai, Isehara, Kanagawa, 259-11 Japan

Magnetic Resonance Imaging

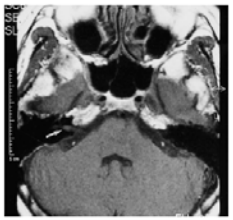


**Figure 1.** Axial image (500/13) demonstrating an extraaxial iso-signal intensity mass simulating sarcoid granuloma involving the VIIth cranial nerve (arrow) at the right internal acoustic canal.

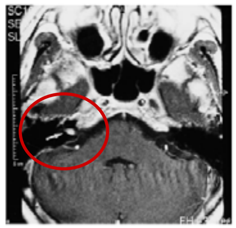


**Figure 2.** Post-gadolinium $T_1$ weighted (500/13) axial image showing markedly enhanced granulomatous lesion (arrow) in the right acoustic canal.

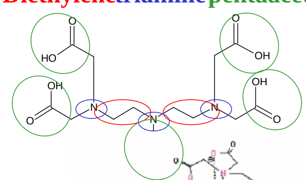
Image Enhancement Shows lesion

Image enhanced By a complex ion

Another Medicinal Example of Complexation

---

**Diethylenetriaminepentaacetic** Acid =DTPA




*Biomacromolecules* 2004, 5, 54–61

**Conformation and Structure of Polymeric Contrast Agents for Medical Imaging**

E. E. Uzgiris,* Harvey Cline, Bahram Moasser, Brian Grimmond, Mohan Amaratunga, Joanne F. Smith, and Gregory Goddard

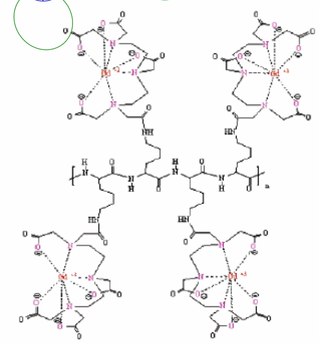



**Figure 2.** Chemical structure of Gd-DTPA-polylysine.

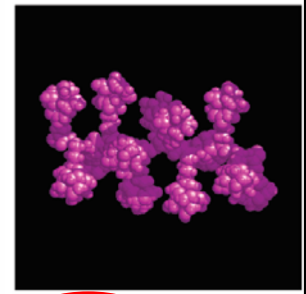


Figure [illegible] Space filling representation of the calculated lowest energy structure of Gd-DTPA-polylysine with complete conjugation of a chain of 80 residues [illegible] the RasMol program in shadowing mode). This structure is a right-hand helix of pitch 3. Peptide chain is in a horizontal orientation. The DTPA moieties are the spherical structures appended to the peptide backbone through the lysine 4 carbon spacer and that spiral around the backbone chain as shown.

---

$$Gd^{3+} + DTPA^{3-} \rightleftarrows Gd(DTPA) \qquad K_f = 10^{23}$$

Stuff patient with delicious gadolinium-DTPA for MRI imaging

**Characteristics of Gadolinium-DTPA Complex:**

What might you want to know?

$$t_{1/2,blood} = 10\,\text{min}$$

$$LD_{50}$$

TABLE 2: **Acute Lethal Toxicity**

| Agent | Dose (mmol/kg) | No. Deaths/ No. Rats | Interpolated $LD_{50}$ (mmol/kg)* |
|---|---|---|---|
| Meglumine diatrizoate | 12 | 0/4 | |
| | 20 | 1/4 | 18 |
| | 28 | 4/4 | |
| $GdCl_3$ | 0.3 | 0/5 | |
| | 0.45 | 2/5 | 0.5 |
| | 0.6 | 5/5 | |
| Meglumine-Gd-EDTA | 0.3 | 2/3 | 0.3 |
| | 1.2 | 5/5 | |
| Dimeglumine-Gd-DTPA | 2.5 | 0/4 | |
| | 7.5 | 0/4 | 10 |
| | 12.5 | 4/4 | |
| $Na_3Ca$-DTPA | 1 | 0/6 | |
| | 2 | 2/6 | 5 |
| | 4 | 0/6 | |
| | 6 | 6/6 | |

* $LD_{50}$ in male and female rats (90–110 g) after intravenous injection.

http://www.ajronline.org/cgi/reprint/142/3/619.pdf

---

What is CN for Gd-DTPA? 7

What is most probable structure?

Trick question! We never saw any structure With 7!

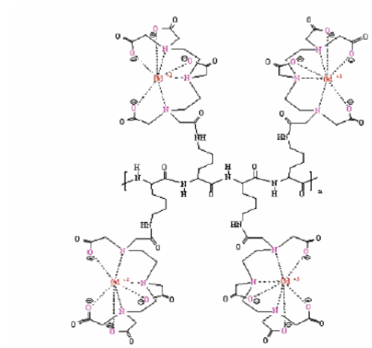



**Figure 2.** Chemical structure of Gd-DTPA-polylysine.


"A" students work (without solutions manual)
~ 10 problems/night.

Dr. Alanah Fitch
Flanner Hall 402
508-3119
afitch@luc.edu

Office Hours Th&F 2-3:30 pm

**Module #18: Complex Ions: Saving future Mr. Litvinenkos**

**Isomers**

If you can read this you will do well in organic chemistry

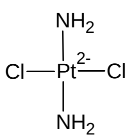
Shapes

A molecule can exist in different **isomers**, which affects it's activity.

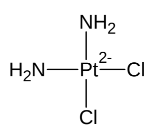
Several types, but most important are stereoisomers

1. geometrical cis/trans — Cis= same side; Trans = opposite side
2. optical mirror image: non-superimposable: chiral

To Cis or not to Cis
Cis Pt, a cancer fighting drug



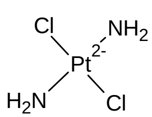

isomers

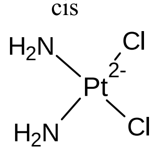



trans

cis

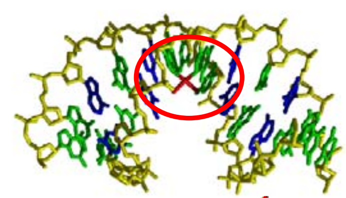
Rotation does Not allow superposition

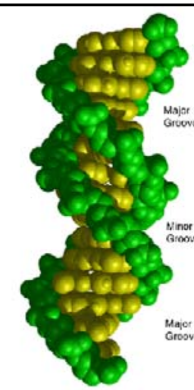


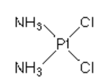




Why configuration is important:
controls shape of molecule
dictates 3D interaction of molecules

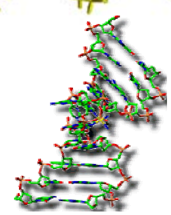
**Anticancer Drug**







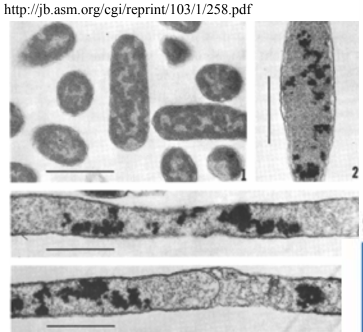

**Cisplatin**



Square planar lets it slide into the DNA grove

Nitrogen on base pair displaces chloro group on cis-platinum to double bind the cis-platinum

The presence of the complex prevents transcription or coding of information and fast growing cancer cells can no longer replicate http://jb.asm.org/cgi/reprint/103/1/258.pdf



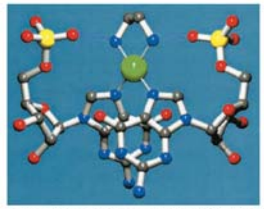


Fig. 2. Amine N-H groups contribute to a macrochelate via hydrogen bonding with the phosphate of GMP in Pt(en)(5'-GMP-N7)₂.

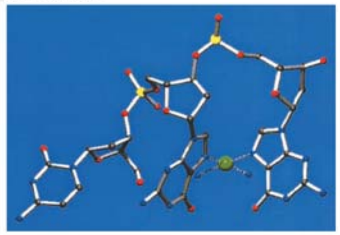


Fig. 4. X-ray structure of d(CGG) chelated to a cisplatin unit, drawn after Admiraal *et al.* (64).

http://www.pnas.org/cgi/reprint/100/7/3611

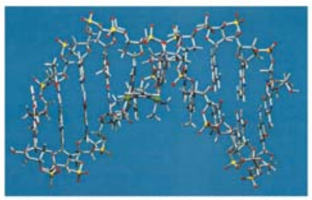


Fig. 5. A double-stranded DNA remains almost unkinked when the dinuclear azole-bridged Pt amine species is chelating to two neighboring guanines (88). Pt, green; P, yellow.

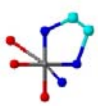
Isomers

Several types, but most important are stereoisomers

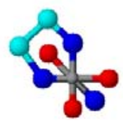
1. geometrical
   cis/trans
2. optical
   mirror image: non-superimposable: chiral


http://images.google.com/imgres?imgurl=http://www.piercecollege.edu/title3/aln/chem102/0_02.gif&imgrefurl=http://www.piercecollege.edu/title3/aln/chem102/Chemistry102_02.html&h=373&w=454&sz=40&hl=en&start=15&um=1&tbnid=AIk1gK8mhiIfDM:&tbnh=105&tbnw=128&prev=/images%3Fq%3Dleft%2Bhand%2Bmirror%2Bimage%26svnum%3D10%26um%3D1%26hl%3Den

Are these all the same molecule?



Optical isomers

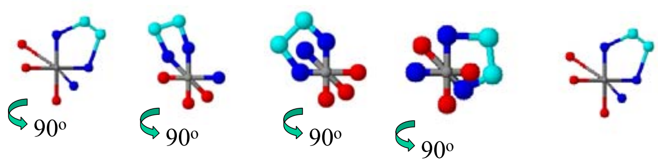


Cis

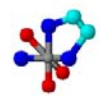
Cis Mirror image

Can we rotate them in space to get the other one?

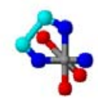
NO




trans

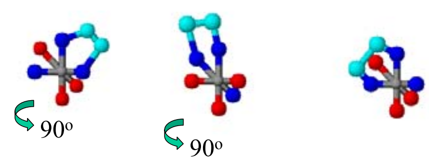


mirror

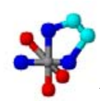


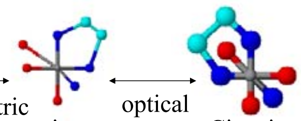
trans/mirror

Rotation of trans results in trans/mirror




3 unique isomers





trans

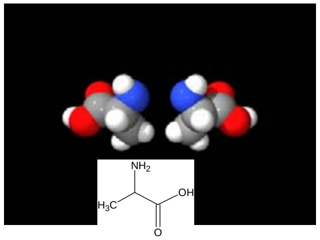
geometric

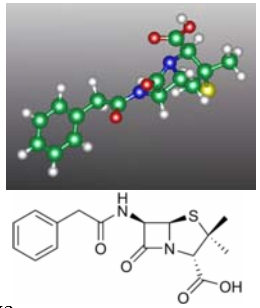
cis

optical

Cis mirror

Why Optical Isomers are important




Wikepedia Alanine: optical isomers

Penicillen's activity is stereoselective.
The antibiotic only works on peptide links of d-alanine which occurs in the cell walls of bacteria – but not in humans. The antibiotic can only kill the bacteria, and not us, because we do not have d-alanine.

To see an animation of the cellular level of how this works:
http://student.ccbcmd.edu/courses/bio141/lecguide/unit1/prostruct/penres.html


"A" students work
(without solutions manual)
~ 10 problems/night.


Dr. Alanah Fitch
Flanner Hall 402
508-3119
afitch@luc.edu


Office Hours Th&F 2-3:30 pm

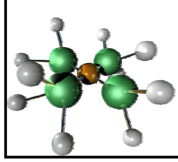
**Module #18:**
**Complex Ions:**
**Saving future**
**Mr. Litvinenkos**

**Complexation Constants**

$$Cu^{2+}_{aq} + NH_{3,aq} \rightleftarrows CuNH^{2+}_{3,aq} \qquad K_{f1}$$
$$CuNH^{2+}_{3,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{2,aq} \qquad K_{f2}$$
$$Cu(NH_3)^{2+}_{2,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{3,aq} \qquad K_{f3}$$
$$Cu(NH_3)^{2+}_{3,aq} + NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{4,aq} \qquad K_{f4}$$

$$Cu^{2+}_{aq} + 4NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{4,aq} \qquad \text{Overall K?}$$

$$K_{rx} = K_{f1}K_{f2}K_{f3}K_{f4} = 2x10^{12}$$



**EXAMPLE calculation**

At what concentration of ammonia is he divalent cation of copper concentration equal to the copper(II) tetraamine concentration? The overall formation constant for the tetraamine complex is $2x10^{12}$. The Pressure is 1 atm.

| know | Don't Know | Red Herrings |
|---|---|---|
| Reaction | $[NH_3]$ | 1 atm |
| $K_f = 2x10^{12}$ | | |
| $[Cu^{2+}]=[Cu(NH_3)_4]^{2+}$ | | |

$$[NH_{3,aq}]^4 = \frac{1}{2x10^{12}}$$

$$Cu^{2+}_{aq} + 4NH_{3,aq} \rightleftarrows Cu(NH_3)^{2+}_{4,aq} \qquad [NH_{3,aq}] = \sqrt[4]{\frac{1}{2x10^{12}}} = 8.409x10^{-4}$$

$$K_f = 2x10^{12} = \frac{[Cu(NH_3)^{2+}_{4,aq}]}{[Cu^{2+}_{aq}][NH_{3,aq}]^4} = \frac{[Cu(NH_3)^{2+}_{4,aq}]}{[Cu(NH_3)^{2+}_{4,aq}][NH_{3,aq}]^4} = \frac{1}{[NH_{3,aq}]^4}$$

$$K_{rx} = K_{f1}K_{f2}K_{f3}K_{f4}K_{f5}K_{f6}\ldots\ldots K_{fn}$$

**What do you observe?**

Lead Complexation Constants

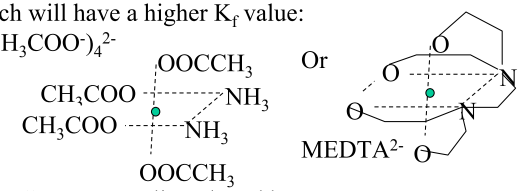
| Ligand | logK1 | logK2 | LogK3 | logK4 | logKf |
|---|---|---|---|---|---|
| F- | 1.4 | 1.1 | | | 2.5 |
| Cl- | 1.55 | 0.6 | -0.4 | -0.7 | 1.05 |
| Br- | 1.8 | 0.8 | -0.1 | -0.3 | 2.2 |
| I- | 1.9 | 1.3 | 0.7 | 0.6 | 4.5 |
| OH- | 6.3 | 4.6 | 2 | | 12.9 |
| Acetate | 2.7 | 1.4 | | | 4.1 |
| Oxalate | 4.9 | 1.9 | | | 6.8 |
| Citrate | 5.7 | | | | 5.7 |
| EDTA | 17.9 | | | | 17.9 |

**Which are polydentate?**
**What do you observe?**

Why so large?

Can you guess which will have a higher $K_f$ value:

$M(NH_3)_2(CH_3COO^-)_4^{2-}$




Because all the "bites" are on one ligand, and because they do not have the motional freedom of six individual bites, the probability of having a portion of EDTA on the Lewis Acid metal center is higher than for the individual ligands.

Therefore: $K_f$ (EDTA) >>>>> $K_f$ (six similar ligands)

Use EDTA to confine metal ions

1. forensic blood sample (O.J. Simpson trial)
2. In food products
3. To purify radioactive metals from water
4. **To treat metal poisoned patients**

**An Example Problem**

$$\frac{1\mu g Pb}{dL} = \frac{0.04826\mu mol}{L} = 4.826x10^{-8}\frac{mol}{L}$$

Children

| Symptom | µg/dL | M |
|---|---|---|
| death | 135 | $6.5x10^{-6}$ |
| encephalopathy | 90 | 4.34 |
| frank anemia | 70 | 3.37 |
| colic | 60 | 2.89 |
| decreased hemoglobin synthesis | 40 | $1.93x10^{-6}$ |
| decreased Vit. D metabolism | 30 | 1.44 |
| decreased nerve conduction velocity | 20 | 0.97 |
| Decreased IQ, hearing, growth | 10 | $0.48x10^{-6}$ |

$$\frac{1\mu g Pb}{dL} = \frac{1\mu g Pb}{0.1L} = \frac{10^{-6} gPb}{(0.1)10^{3}\, gwater} = \frac{10x10^{-9} gPb}{gwater} = 10ppb$$

**EXAMPLE** If a 30 kg child comes in with symptoms of colic, seizures, persistent fatigue, and is known to have eaten paints we diagnose lead poisoning. A clinical test shows the child to have 40 µg/dL blood lead. Our first goal is to lower the amount of lead in the blood stream.

Blood volume in an adult is about 4 L. Estimate a blood volume of 3 L in a child. We will need to give this child some mg amount of a ligand to form a complex ion with lead that is soluble so that it can be carried to the kidneys and filtered into urine and removed.

What would be the equilibrium blood lead concentration if we gave the child 28.7 mg CaEDTA/kg weight//day? The molecular weight of $CaNa_2EDTA$ is 374.28. The child is 30 kg, estimated blood volume of 3 L. Estimate EDTA is adsorbed from stomach to blood stream.

What would be the equilibrium blood lead concentration if we gave the child 28.7 mg CaEDTA/kg weight//day? The molecular weight of $CaNa_2EDTA$ is 374.28. The child is 30 kg, estimated blood volume of 3 L. Estimate EDTA is adsorbed from stomach to blood stream.

| Know | Don't Know |
|---|---|
| 40 ug/dLBlood lead value | molarity blood lead |
| 3 L volume of blood | |
| 28.7 mg EDTA | molarity EDTA |
| m.w. 374.28 | |
| $K_f = 10^{17.9}$ | equil. conc. lead |

$$[EDTA_{init}] = \frac{(28.7mgEDTA)\left(\frac{1g}{10^3 mg}\right)\left(\frac{1mole}{374.28g}\right)}{3L} = 7.66x10^{-5}\ M$$

$$[Pb_{init}] = \left(\frac{40\mu g Pb}{dL}\right)\left(\frac{10dL}{L}\right)\left(\frac{1mole}{207.2g}\right)\left(\frac{1g}{10^6\ \mu g}\right) = 1.93x10^{-6}\ M$$

$$\log K_f = 10^{17.9}$$

Is this K value large ?

or small?

What does that mean for the extent of the reaction?

$$EDTA^{4-}_{aq} + Pb^{2+}_{aq} \rightleftarrows PbEDTA^{2-}_{aq} \qquad K_f = 10^{17.9} = 7.93x10^{17}$$

What does this mean for the magnitude of change, x, in the reaction?

| $EDTA^{4-}_{aq}$ + | $Pb^{2+}_{aq}$ $\rightleftarrows$ | $PbEDTA^{2-}_{aq}$ |
|---|---|---|
| $[EDTA^{4-}_{aq,init}]$ | $[Pb^{2+}_{aq,init}]$ | 0 |
| $-x$ | $-x$ | $+x$ |

How will this inform our thinking on how to solve the problem?

2 strategies are possible

1. start with an equilibrium problem
2. first assume a complete reaction $EDTA^{4-}_{aq} + Pb^{2+}_{aq} \rightarrow PbEDTA^{2-}_{aq}$
   then calculate dissociation $PbEDTA^{2-}_{aq} \rightleftarrows EDTA^{4-}_{aq} + Pb^{2+}_{aq}$

What would be the equilibrium blood lead concentration if we gave the child 28.7 mg CaEDTA/kg weight//day? The molecular weight of $CaNa_2EDTA$ is 374.28. The child is 30 kg, estimated blood volume of 3 L. Estimate EDTA is adsorbed from stomach to blood stream.

| | $EDTA^{4-}$ | $Pb^{2+}$ | $EDTAPb^{2-}$ |
|---|---|---|---|
| stoi | 1 | 1 | 1 |
| Init | $7.66x10^{-5}$ | $1.93x10^{-6}$ | 0 |
| Change | -x | -x | +x |
| Equil | $7.44x10^{-5}$-x | $1.93x10^{-6}$-x | x |

$$K_f = \frac{[PbEDTA^{2-}_{aq,eq}]}{[EDTA^{4-}_{aq,eq}][Pb^{2+}_{aq,eq}]} = \frac{x}{([EDTA^{4-}_{init}] - x)(1.93x10^{-6} - x)}$$

$$K_f([EDTA^{4-}_{init}] - x)([Pb_{init}] - x) = x$$

$$K_f([EDTA^{4-}_{init}][Pb_{init}] - [Pb_{init}]x - [EDTA^{4-}_{init}]x + x^2) = x$$

$$K_f[EDTA^{4-}_{init}][Pb_{init}] - K_f x[Pb_{init}] - K_f x[EDTA^{4-}_{init}] + K_f x^2 = x$$

$$K_f x^2 - K_f x[Pb_{init}] - K_f x[EDTA^{4-}_{init}] - x + K_f[EDTA^{4-}_{init}][Pb_{init}] = 0$$

$$K_f x^2 - K_f x[Pb_{init}] - K_f x[EDTA^{4-}_{init}] - x + K_f[EDTA^{4-}_{init}][Pb_{init}] = 0$$

$$K_f x^2 - x(K_f[Pb_{init}] + K_f[EDTA^{4-}_{init}] + 1) + K_f[EDTA^{4-}_{init}][Pb_{init}] = 0$$

$$a = K_f = 7.943x10^{17}$$

$$b = -(K_f[Pb_{init}] + K_f[EDTA^{4-}_{init}] + 1)$$

$$b = -[(7.93x10^{17})(1.93x10^{-6}) + (7.93x10^{17})(7.66x10^{-5}) + 1] = -6.24x10^{13}$$

$$c = K_f[EDTA^{4-}_{init}][Pb_{init}] = (7.93x10^{17})(1.93x10^{-6})(7.66x10^{-5}) = 1.17x10^8$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-(-6.24x10^{13}) \pm \sqrt{(-6.24x10^{13})^2 - 4(7.943x10^{17})(1.17x10^8)}}{2(7.943x10^{17})}$$

$$x = \frac{6.24x10^{13} \pm \sqrt{3.89x10^{27} - 3.73x10^{26}}}{1.59x10^{18}}$$

$$x = \frac{6.24x10^{13} \pm \sqrt{3.52x10^{27}}}{1.59x10^{18}}$$

$$x = \frac{6.24x10^{13} \pm 5.93104x10^{13}}{1.59x10^{18}}$$

$$x = \frac{6.24x10^{13} \pm 5.93104x10^{13}}{1.59x10^{18}}$$

$x = 7.66x10^{-5}$

$x = 1.93x10^{-6}$

No conc. is ever exactly zero. This is a case where we should've started by considering

$$EDTA^{4-}_{aq} + Pb^{2+}_{aq} \rightleftarrows PbEDTA^{2-}_{aq}$$

$$7.467x10^{-5} \quad 0 \quad 1.93x10^{-6}$$

$$+x \quad +x \quad -x$$

In the next 2 slides (which may Be skipped) x is solved.

$[Pb^{2+}{}_{eq}] = [Pb^{2+}{}_{init}] - x = 1.93x10^{-6} - x$

$[Pb^{2+}{}_{eq}] = 1.93x10^{-6} - 7.66x10^{-5} = neg\ answer$

$[Pb^{2+}{}_{eq}] = 1.93x10^{-6} - 1.93x10^{-6} = 0$

Of these two the second Answer is best,

$$x = \left[Pb^{2+}_{aq}\right] = 3.17x10^{-20}\ M = 6.79x10^{-13}\ \frac{\mu g}{dL}$$

$[Pb^{2+}_{eq}] = 0$

$[PbEDTA^{2-}_{de}] = 1.93x10^{-6}$

$[EDTA^{4-}_{eq}] = [EDTA^{4-}_{init}] - 1.93x10^{-6} = 7.66x10^{-5} - 1.93x10^{-6} = 7.467x10^{-5}$

---

What would be the equilibrium blood lead concentration if we gave the child 28.7 mg CaEDTA/kg weight//day? The molecular weight of $CaNa_2EDTA$ is 374.28. The child is 30 kg, estimated blood volume of 3 L. Estimate EDTA is adsorbed from stomach to blood stream.

$$\left[EDTA_{init}\right] = 7.66x10^{-5}\ M \qquad \left[Pb_{init}\right] = 1.93x10^{-6}\ M$$

$$CaNa_2EDTA_s \rightleftarrows Ca^{2+}_{aq} + 2Na^{2+}_{aq} + EDTA^{4-}_{aq}$$

$$EDTA^{4-}_{aq} + Pb^{2+}_{aq} \rightleftarrows PbEDTA^{2-}_{aq} \qquad K_f = 10^{17.9} = 7.93x10^{17}$$

So large – complete reaction

From EDTA $\quad (7.66x10^{-5}\ M)(3L) = 3.20x10^{-4}\ mole_{PbEDTA}$

From Pb $\quad (1.93x10^{-6}\ M)(3L) = 5.79x10x10^{-6}\ mole_{PbEDTA}$ Limiting Reagent

$$\left[EDTA_{after\ L.R.}\right] = \frac{3.20x10^{-4} - 5.79x10^{-6}}{3L} = 7.467x10^{-5} \qquad \left[Pb_{after\ L.R.}\right] = 0$$

$$\left[PbEDTA_{after\ L.R.}\right] = \frac{5.79x10^{-6}}{3L} = 1.937x10^{-6}$$

---

What would be the equilibrium blood lead concentration if we gave the child 28.7 mg CaEDTA/kg weight//day? The molecular weight of $CaNa_2EDTA$ is 374.28. The child is 30 kg, estimated blood volume of 3 L. Estimate EDTA is adsorbed from stomach to blood stream.

| | $EDTA^{4-}$ | $Pb^{2+}$ | $EDTAPb^{2-}$ |
|---|---|---|---|
| stoi | 1 | 1 | 1 |
| Init | $7.44x10^{-5}$ | 0 | $1.93x10^{-6}$ |
| Change | +x | x | -x |
| Equil | $7.44x10^{-5}$ | x | $1.93x10^{-6}$ |
| Assume | $x<<<7.44x10^{-5}$ | | $x<<1.93x10^{-6}$ |

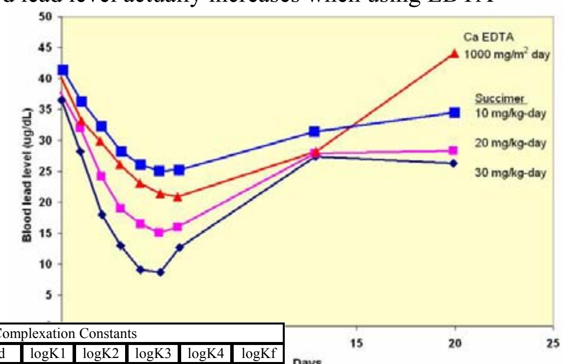
$$K_f = 7.93x10^{17} = \frac{\left[PbEDTA^{2-}_{aq,eq}\right]}{\left[EDTA^{4-}_{aq,eq}\right]\left[Pb^{2+}_{aq,eq}\right]} = \frac{\left[PbEDTA^{2-}_{after\ L.R.}\right] - x}{\left(\left[EDTA^{4-}_{after\ L.R.}\right] + x\right)x} \approx \frac{\left[PbEDTA^{2-}_{after\ L.R.}\right]}{\left(\left[EDTA^{4-}_{after\ L.R.}\right]\right)x}$$

$$x = \frac{\left[PbEDTA^{2-}_{after\ L.R.}\right]}{\left(\left[EDTA^{4-}_{after\ L.R.}\right]\right)7.93x10^{17}} = \frac{1.93x10^{-6}}{(7.44x10^{-5})7.93x10^{17}} = 3.17x10^{-20}$$

$$x = 3.17x10^{-20}\ M = 6.79x10^{-13}\ \frac{\mu g}{dL}$$

---

Blood lead level actually increases when using EDTA Why?

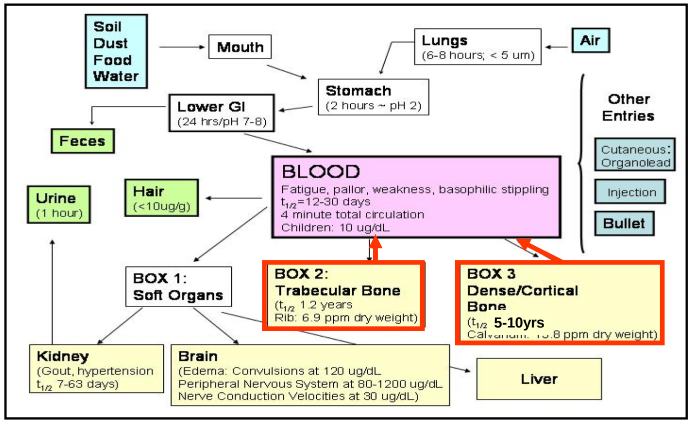



Lead Complexation Constants

| Ligand | logK1 | logK2 | logK3 | logK4 | logKf |
|---|---|---|---|---|---|
| F- | 1.4 | 1.1 | | | 2.5 |
| Cl- | 1.55 | 0.6 | -0.4 | -0.7 | 1.05 |
| Br- | 1.8 | 0.8 | -0.1 | -0.3 | 2.2 |
| I- | 1.9 | 1.3 | 0.7 | 0.6 | 4.5 |
| OH- | 6.3 | 4.6 | 2 | | 12.9 |
| Acetate | 2.7 | 1.4 | | | 4.1 |
| Oxalate | 4.9 | 1.9 | | | 6.8 |
| Citrate | 5.7 | | | | 5.7 |
| EDTA | 17.9 | | | | 17.9 |

The constant if very large For lead – complete reaction (as we just found out!)

Will search for and mobilize Other forms of lead



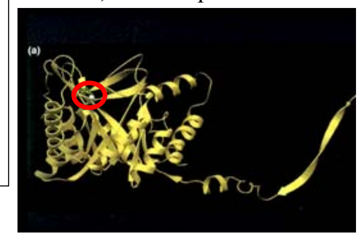

Essentially EDTA is on a search and destroy mission to remove lead.

Any other problems?
Why isn't this therapy the best one medically?

EDTA

| Metal | $\log K_f$ |
|---|---|
| $Pb^{2+}$ | 17.9 |
| $Fe^{2+}$ | 14.4 |
| $Fe^{3+}$ | 25.1 |
| $Cu^{2+}$ | 18.8 |
| $Zn^{2+}$ | 16.5 |

Removes other essential Metals; some imp. For structure



ALAD helps construct the Porphyrin ring for hemoglobin.
$Zn^{2+}$ helps in its functioning

An Example of rate constants in the real world: context and calculations

## Toxicology of Radioactive Exposure

$${}^{210}_{84}Po \rightarrow {}^{4}_{2}He + {}^{206}_{92}Pb$$

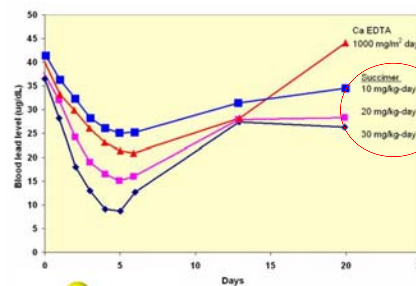
**Alexander Litvinenko, former Russian KGB agent poisoned with Polonium on Nov. 1, died Nov. 23, 2006**

190 ng dose suspected

Could Po be Removed using Complexation reactions?

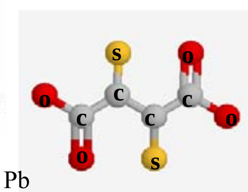
YES!!

Complexation of Po and Pb for medical treatment



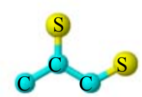

Alternative is "succimer"

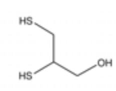
Trade name for Dimercaptosuccinic acid, DMSA

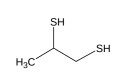


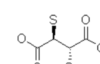
Pb♥ S

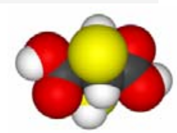
Reagents for Pb Contain S









Dimercaptopropane, DMPS

Aka British anti-Lewisite

**Titre du document / Document title**
**Combined chelation treatment for polonium after simulated wound contamination in rat**
**Auteur(s) / Author(s)**
VOLF V. (1) ; RENCOVA J. ; JONES M. M. ; SINGH P. K. ;
**Affiliation(s) du ou des auteurs / Author(s) Affiliation(s)**
(1) Inst. Toxicologie, Forschungszent. Karlsruhe: Tech. Umwelt, 76021 Karlsruhe, ALLEMAGNE

**Résumé / Abstract**
Contaminated puncture wounds were simulated in rat by intramuscular injection of [210]Po. The aim of the study was to determine the effectiveness of chelation treatment as a function of time, dosage, and route of chelate administration. Ten newly synthesized substances containing vicinal sulphydryl and carbodithioate groups were used and their effect was compared with that of chelators clinically applicable in man-BAL (2,3-dimercaptopropane-1-ol), DMPS (2,3-dimercaptopropane-1-sulphonate), **DMSA** (meso-2,3-dimercaptosuccinic acid), and DDTC (sodium diethylamine-N-carbodithioate). **The results indicate first that complete removal of [210]Po from the injection site is achieved by only two local injections of DMPS, beginning as late as 2 h after injection of [210]Po. Second, many of the substances used merely induce translocation of [210]Po from the injection site into other tissues.** Third, a combined local treatment at the injection site with DMPS plus repeated systemic, subcutaneous, treatments with HOEtTTC (N,N'-di-(2-hydroxyethyl)ethylenediamine-N,N'-biscarbodithioate), a derivative of DDTC, results after 2 weeks in a reduction of the estimated total body retention of [210]Po to about one-third of that in untreated controls. In the latter case the cumulative excretion of [210]Po increased from 8 to 54%, mainly via the faeces.
**Revue / Journal Title**
International journal of radiation biology (Int. j. radiat. biol.) **ISSN** 0955-3002
**Source / Source**
1995, vol. 68, no4, pp. 395-404 (19 ref.)

**Titre du document / Document title**
**Mobilization and detoxification of polonium-210 in rats by 2,3-dimercaptosuccinic acid and its derivatives**
**Auteur(s) / Author(s)**
RENCOVA J. (1) ; VOLF V. (1) ; JONES M. M. (2) ; SINGH P. K. (2) ;
**Affiliation(s) du ou des auteurs / Author(s) Affiliation(s)**
(1) National Institute of Public Health, Centre of Industrial Hygiene and Occupational Diseases, Šrobárova 48, 100 42 Praha, TCHEQUE, REPUBLIQUE
(2) Vanderbilt University, Department of Chemistry, PO Box 1583, Nashville, Tennessee 37235, ETATS-UNIS

**Résumé / Abstract**
Purpose: **To reduce retention and toxicity of the alpha particle emitter polonium-210** in rats by newly developed chelating agents. Materials and methods: Repeated subcutaneous chelation was conducted after intravenous injection of [210]Po nitrate. For reduction of [210]Po retention the treatment with vicinal dithiols meso-and rac-2,3-dimercaptosuccinic acid (**DMSA**), mono-i-amylmeso-2,3-dimercapto succinate (Mi-ADMS) and mono-N-(i-butyl)-meso-2,3-dimercapto succinamide (Mi-BDMA) were used. For the reduction of toxic effects of [210]Po, treatment effectiveness of Mi-BDMA was compared with that of N,N'-di(2-hydroxyethyl)ethylenediamine-N,N'-biscarbodithioate (HO-EtTTC, reference compound). Results: Treatment with meso-DMSA and rac-DMSA altered the main excretion route of [210]Po, reduced its contents in the liver but increased its deposition in the kidneys. Treatment with Mi-ADMS or Mi-BDMA increased total excretion of [210]Po, mainly via the faeces. Only Mi-BDMA decreased [210]Po levels in the kidneys. The effectiveness of all chelators decreased with delay in the start of treatment. **In a survival study, the lives of rats treated early with Mi-BDMA or delayed with HOEtTTC were prolonged three-fold when compared with rats receiving a lethal amount of [210]Po only.** Conclusions: Of the vicinal dithiols examined, Mi-BDMA was the best mobilizing chelating agent for [210]Po and it reduced [210]Po toxicity when the treament started immediately. However, the detoxification efficacy of the immediate treatment with HOEtTTC, observed in our previous study, was superior to that of the present result with Mi-BDMA.
**Revue / Journal Title**
International journal of radiation biology (Int. j. radiat. biol.) **ISSN** 0955-3002
**Source / Source**
2000, vol. 76, no10, pp. 1409-1415 (21 ref.)


"A" students work
(without solutions manual)
~ 10 problems/night.

Dr. Alanah Fitch
Flanner Hall 402
508-3119
afitch@luc.edu

Office Hours Th&F 2-3:30 pm

**Module #18:**
**Complex Ions:**
**Saving future**
**Mr. Litvinenkos**

What you need to know

What you need to know

1. Ions and elements likely to be ligands
2. Types of structures likely to be chelates
3. Coordination number
4. Which suggests structure
5. Which suggests isomers, geometric and stereo (mirror)
6. Why chelates have larger Kf
7. Equilibrium calculation using Kf
8. Know what a "large Kf" is
9. Interpret a diagram of fractional complexation vs p(ligand)
10. Explain how that diagram helps you plan for qualitative analysis (e.g. your current 101 labs)
11. Explain one of the four examples of complexation in biology
    or
    One of one examples of complexation in geochemistry


"A" students work (without solutions manual)
~ 10 problems/night.

Dr. Alanah Fitch
Flanner Hall 402
508-3119
afitch@luc.edu

Office Hours Th&F 2-3:30 pm

**Module #18:
Complex Ions:
Saving future
Mr. Litvinenkos**

END