

INTRODUCCIÓN A LA QUÍMICA DE COORDINACIÓN

QUÍMICA INORGÁNICA I

PROF. PAULINO GUILLERMO ZERÓN ESPINOSA



Aducto

Ácido de
Lewis

A

+

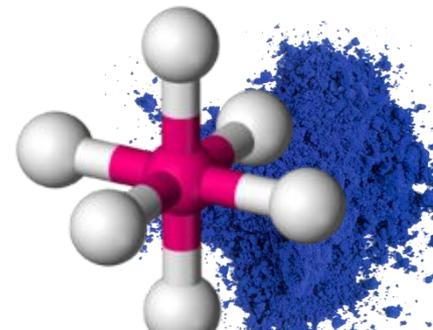
Base de
Lewis

:B



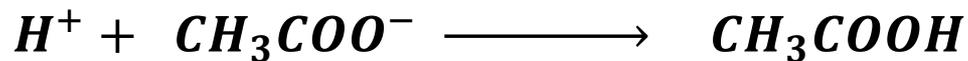
Aducto

A — B





Compuestos Covalentes



Electrones Cedidos

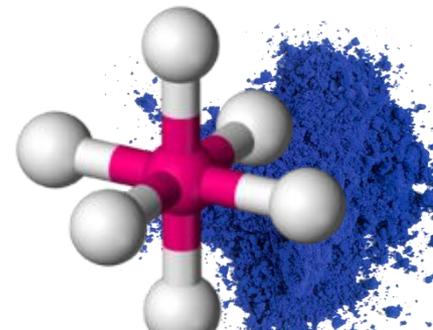
Aducto

Naturaleza

Electrones Prestados



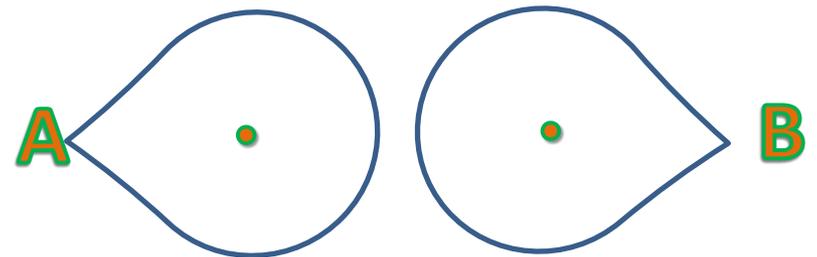
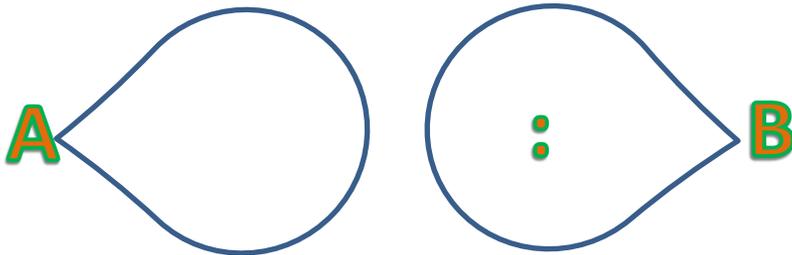
Enlace Covalente Coordinado



Compuestos covalentes coordinados

VS

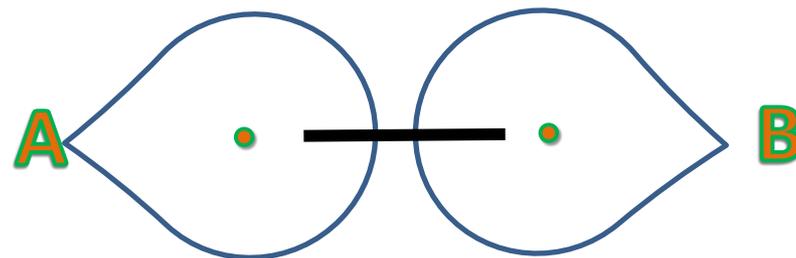
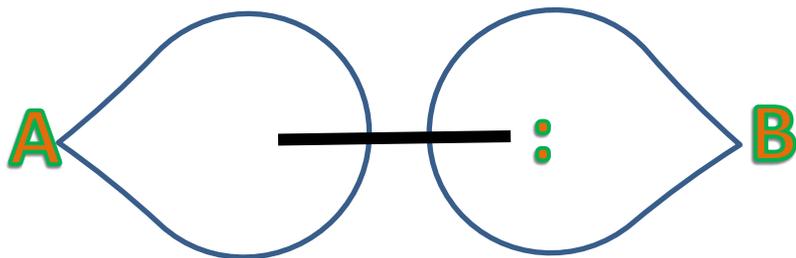
Compuestos covalentes



Compuestos covalentes coordinados

VS

Compuestos covalentes

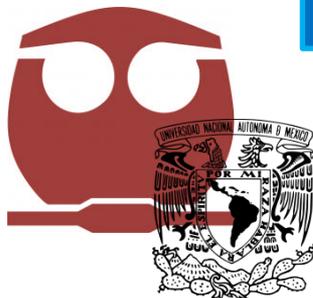


**Compuestos
covalentes
coordinados**

VS

**Compuestos
covalentes**





Ácidos de Lewis

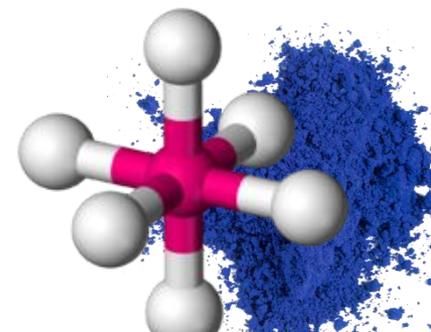
1 IA	New Original	Alcalinos	Actínidos	Solid																18 VIIA										
1	H 1.0078	21 Sc Escandio 44.955910	22 Ti Titanio 47.867	23 V Vanadio 50.9415	24 Cr Cromo 51.9961	25 Mn Manganeso 54.938049	26 Fe Hierro 55.8457	27 Co Cobalto 58.933200	28 Ni Níquel 58.6934	29 Cu Cobre 63.546	30 Zn Zinc 65.409	39 Y Itrio 88.90585	40 Zr Circonio 91.224	41 Nb Niobio 92.90638	42 Mo Molibdeno 95.94	43 Tc Tecnecio (98)	44 Ru Rutenio 101.07	45 Rh Rodio 102.90550	46 Pd Paladio 106.42	47 Ag Plata 107.8682	48 Cd Cadmio 112.411	72 Hf Hafnio 178.49	73 Ta Tántalo 180.9479	74 W Wolframio 183.84	75 Re Renio 186.207	76 Os Osmio 190.23	77 Ir Iridio 192.217	78 Pt Platino 195.078	79 Au Oro 196.96655	80 Hg Mercurio 200.59

Atomic masses in parentheses are those of the most stable or common isotope.

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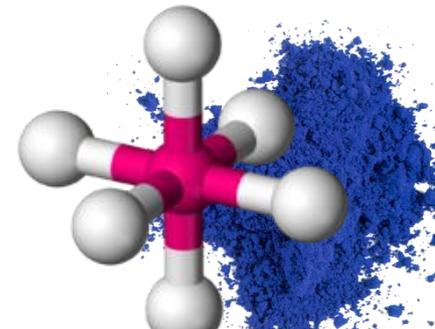
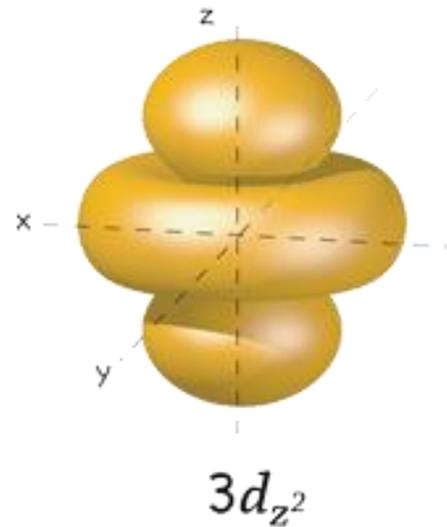
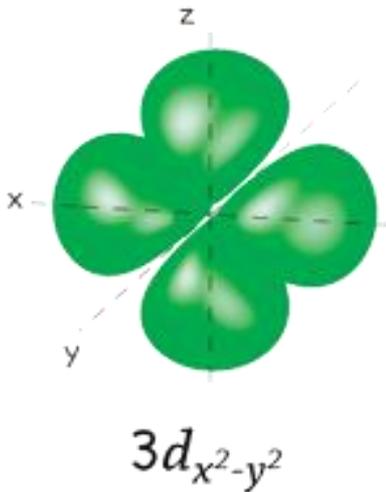
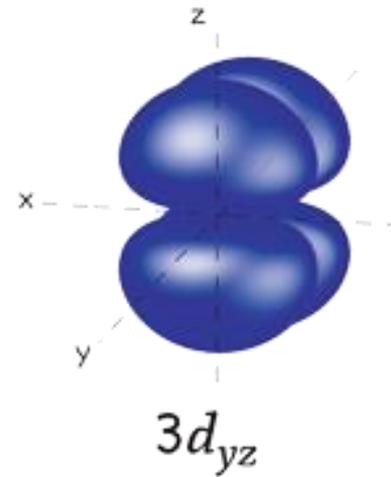
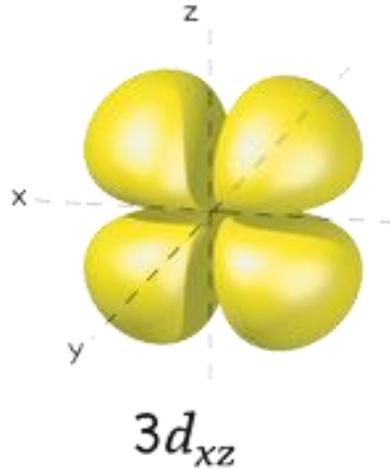
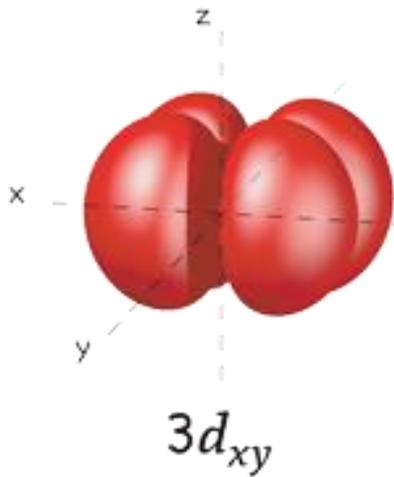
57 La Lantano 138.9055	58 Ce Cerio 140.116	59 Pr Praseodimio 140.90765	60 Nd Neodimio 144.24	61 Pm Prometio (145)	62 Sm Samario 150.36	63 Eu Europio 151.964	64 Gd Gadolinio 157.25	65 Tb Terbio 158.92534	66 Dy Disprosio 162.500	67 Ho Holmio 164.93032	68 Er Erbio 167.259	69 Tm Tulio 168.93421	70 Yb Iterbio 173.04	71 Lu Lutecio 174.967
89 Ac Actinio (227)	90 Th Torio 232.0381	91 Pa Protactinio 231.03688	92 U Uranio 238.02891	93 Np Neptunio (237)	94 Pu Plutonio (244)	95 Am Americio (243)	96 Cm Curio (247)	97 Bk Berkelio (247)	98 Cf Californio (251)	99 Es Einsteinio (252)	100 Fm Fermio (257)	101 Md Mendelevio (258)	102 No Nobelio (259)	103 Lr Lawrencio (262)

Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.





¿Por qué metales de transición?





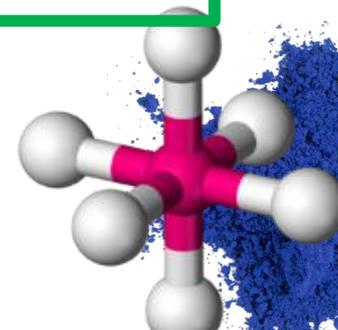
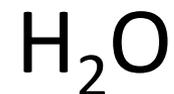
Bases de Lewis | Ligantes

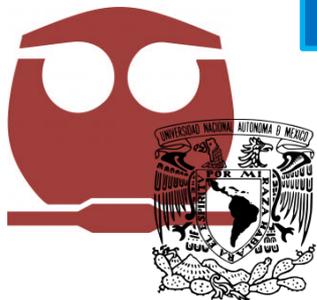
Inorgánicos

Cargados



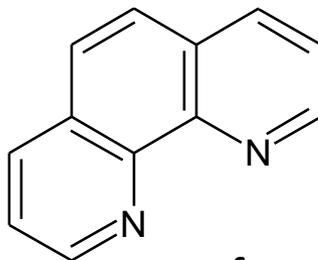
Neutros



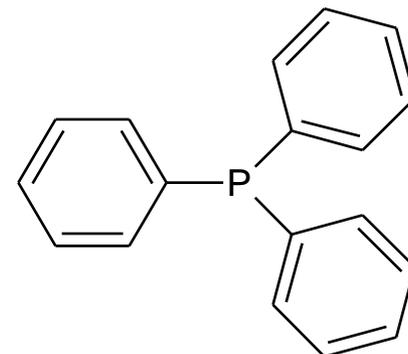


Bases de Lewis | Ligantes

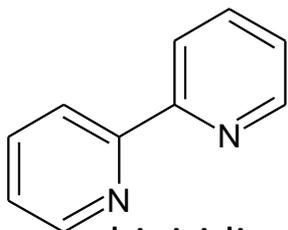
Orgánicos



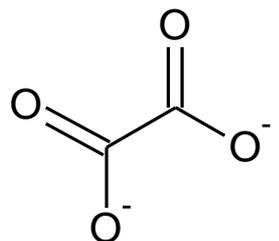
fenantrolina



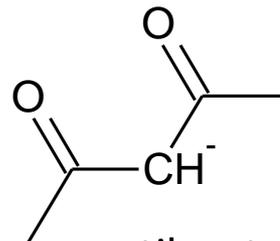
trifenilfosfina



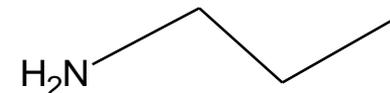
bipiridina



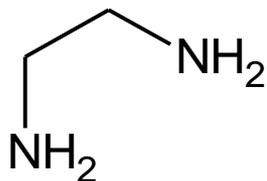
oxalato



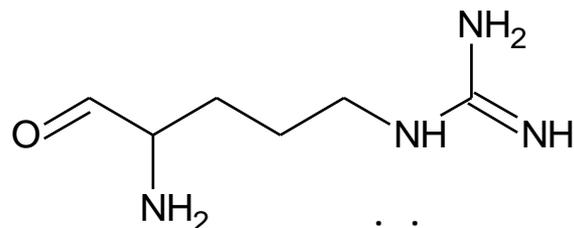
acetilacetonato



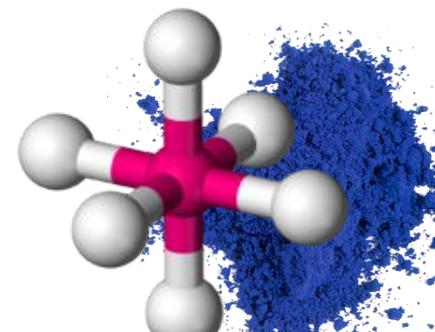
propilamina

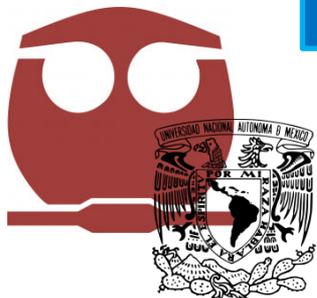


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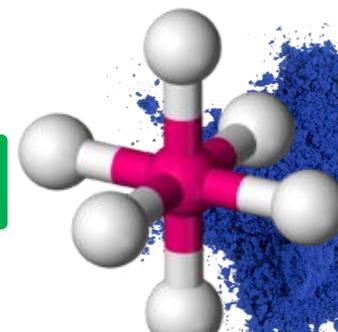
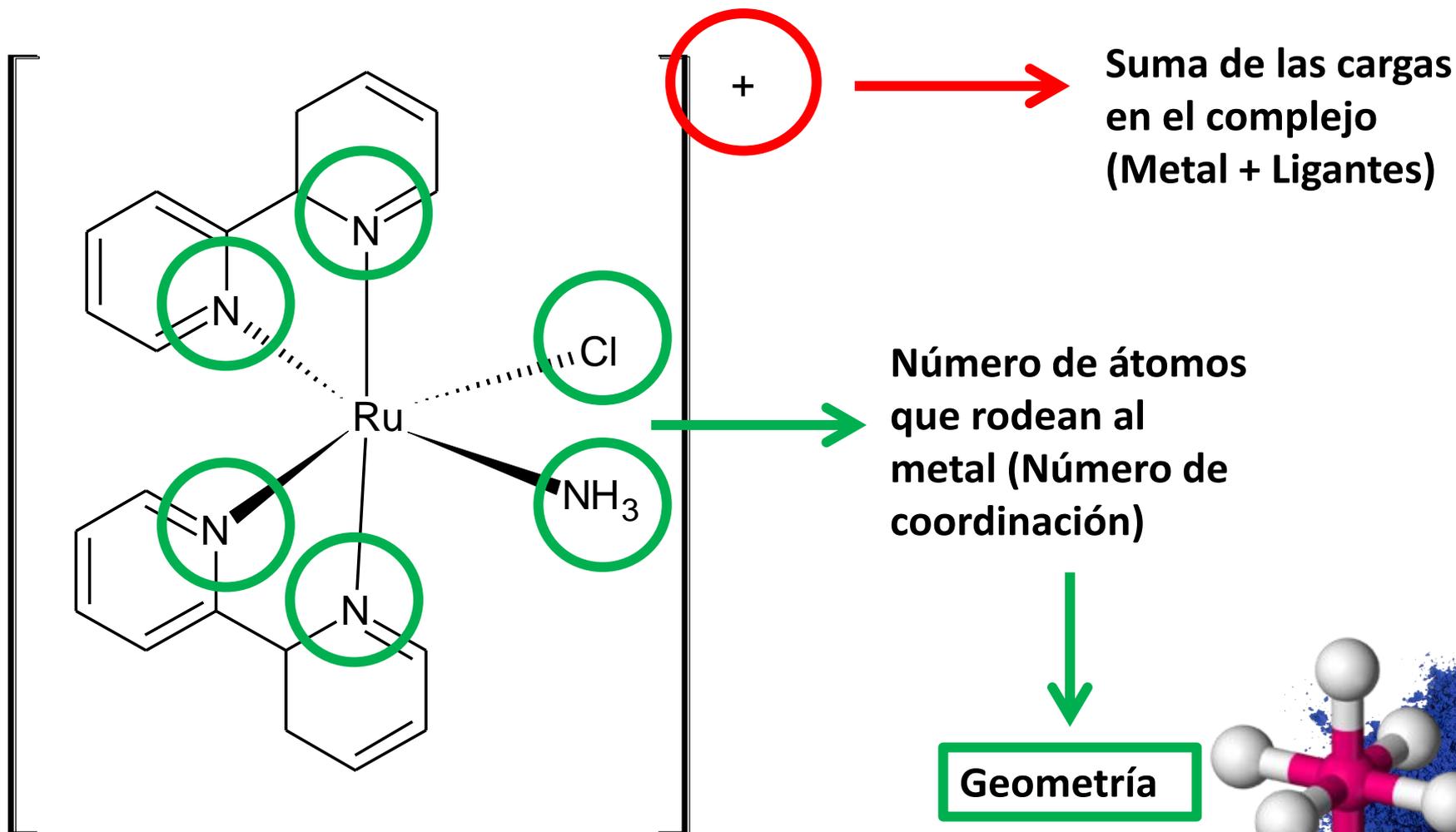


arginina



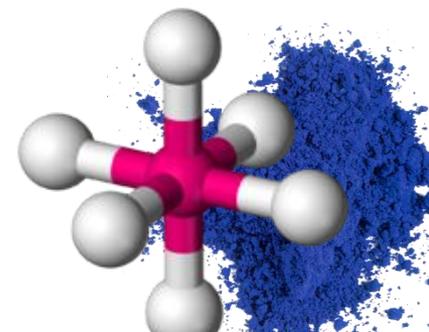
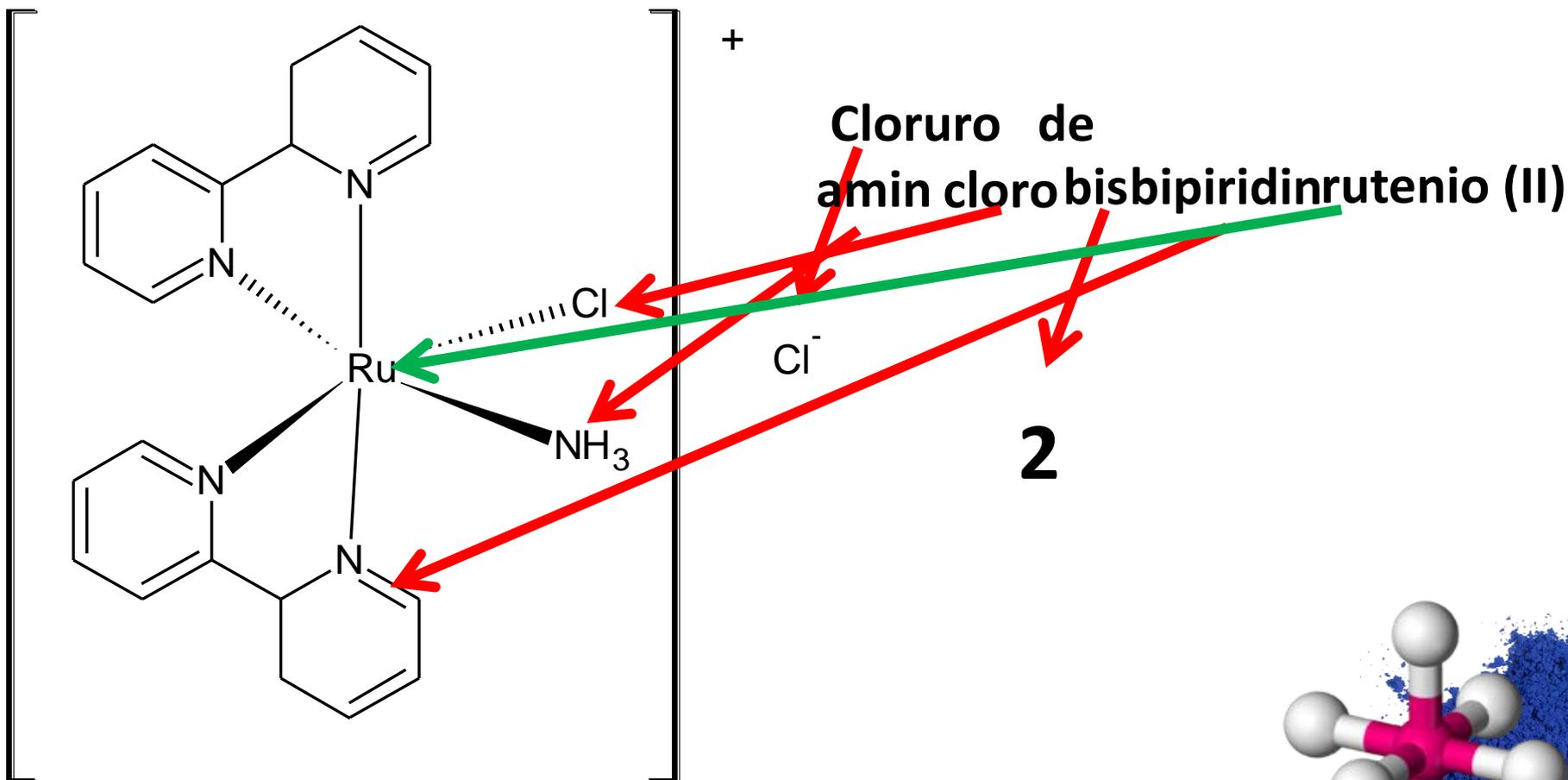


Compuestos de Coordinación





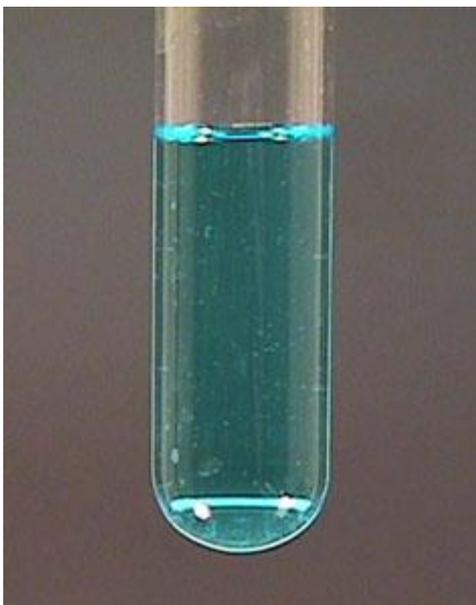
Nomenclatura de compuestos de coordinación



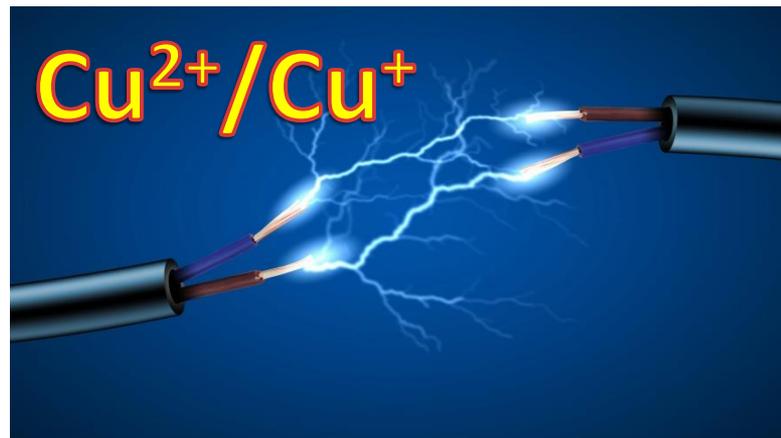


Características

Color



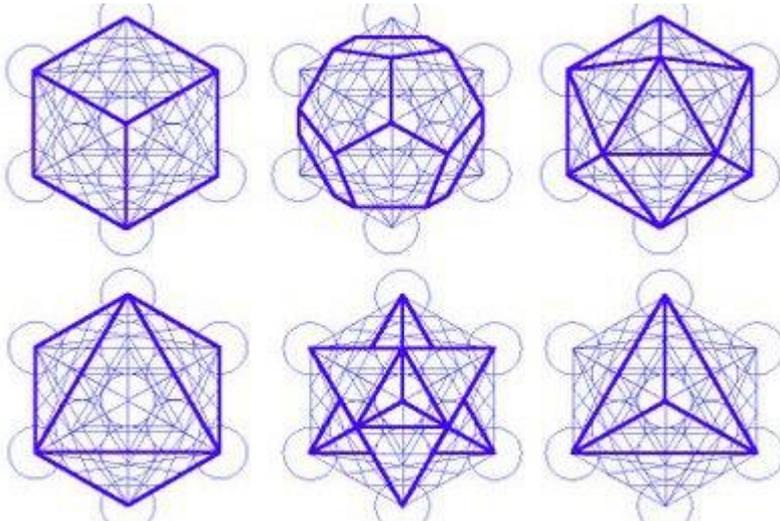
REDOX



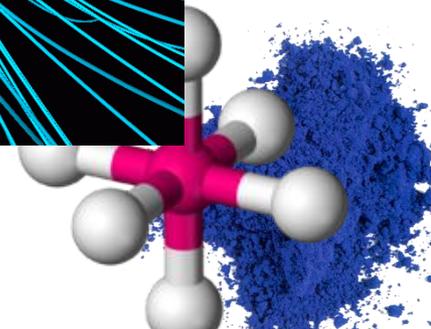
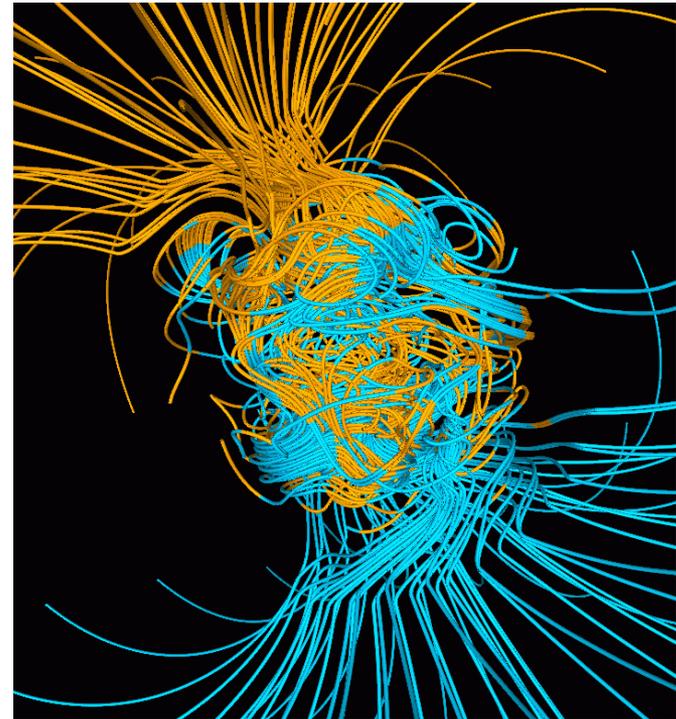


Características

Geometría



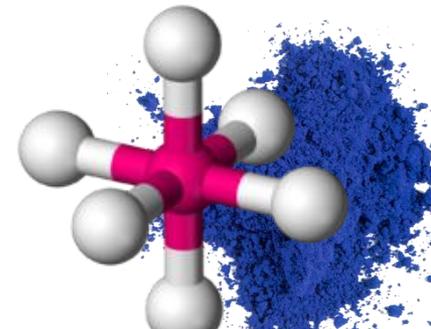
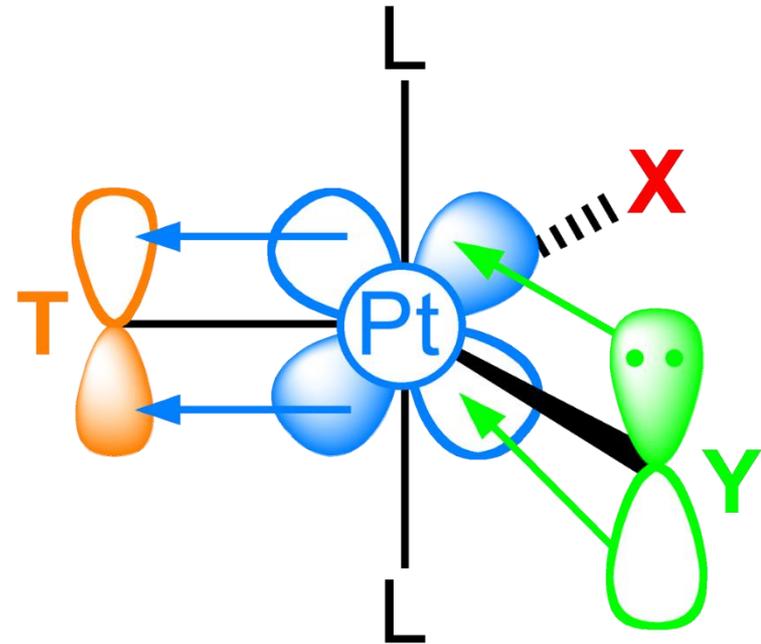
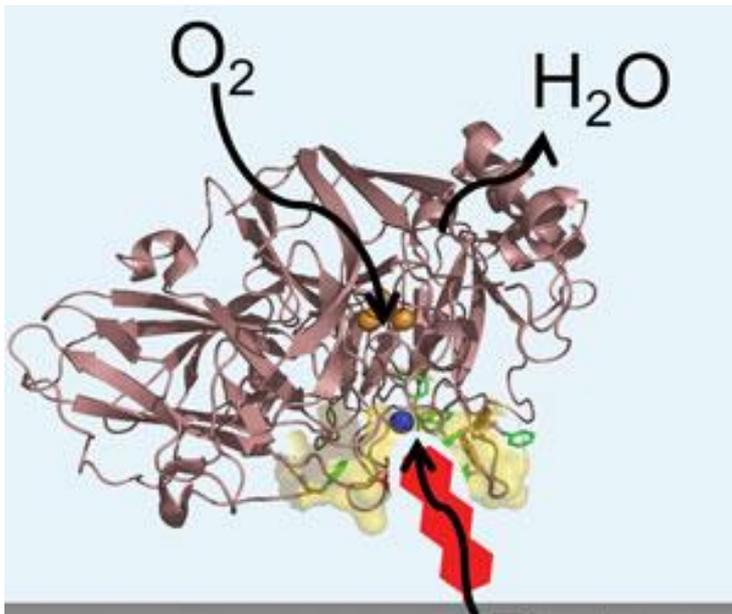
Paramagnetismo





Características

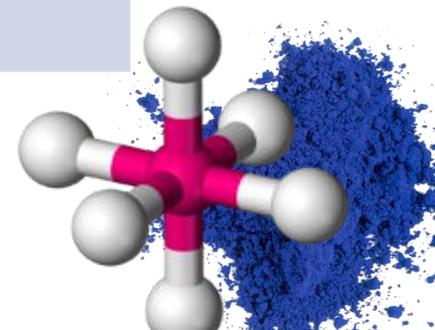
Reactividad





Geometrías más comunes

Número de Coordinación	Geometrías
4	Cuadrado, Tetraedro
5	Bipirámide trigonal, Pirámide de base cuadrada
6	Octaedro

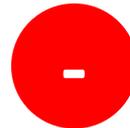
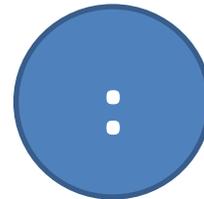
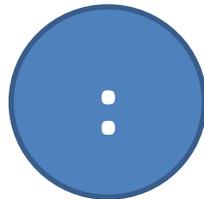




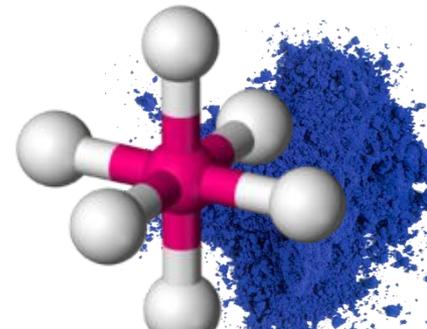
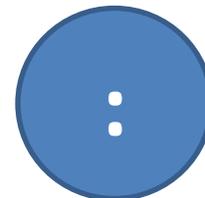
Teoría de Campo Cristalino

Repulsiones Electroestáticas

Electrones
provenientes
de los ligantes

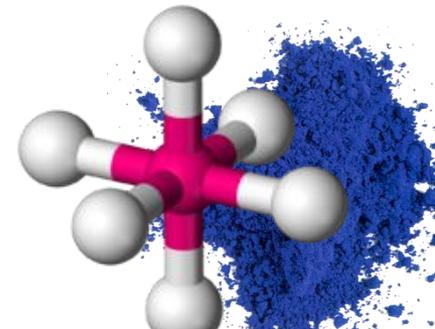
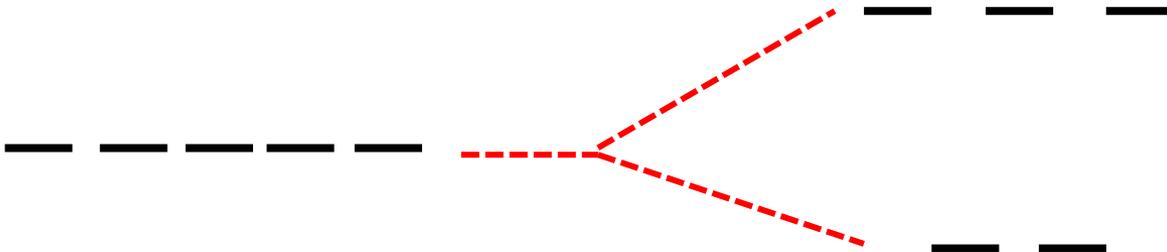
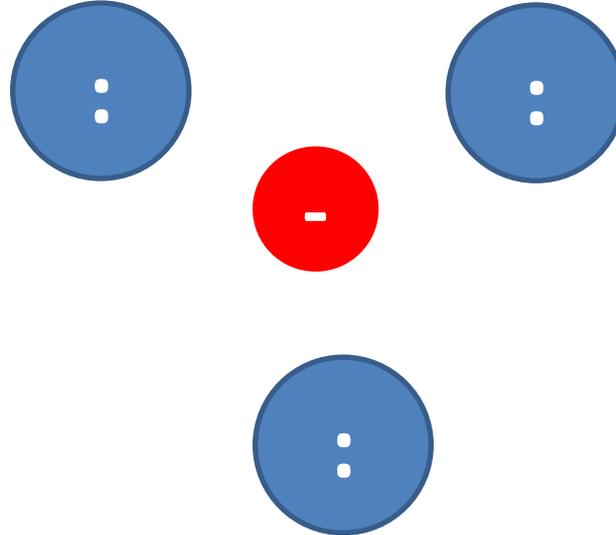


Orbitales del
Metal





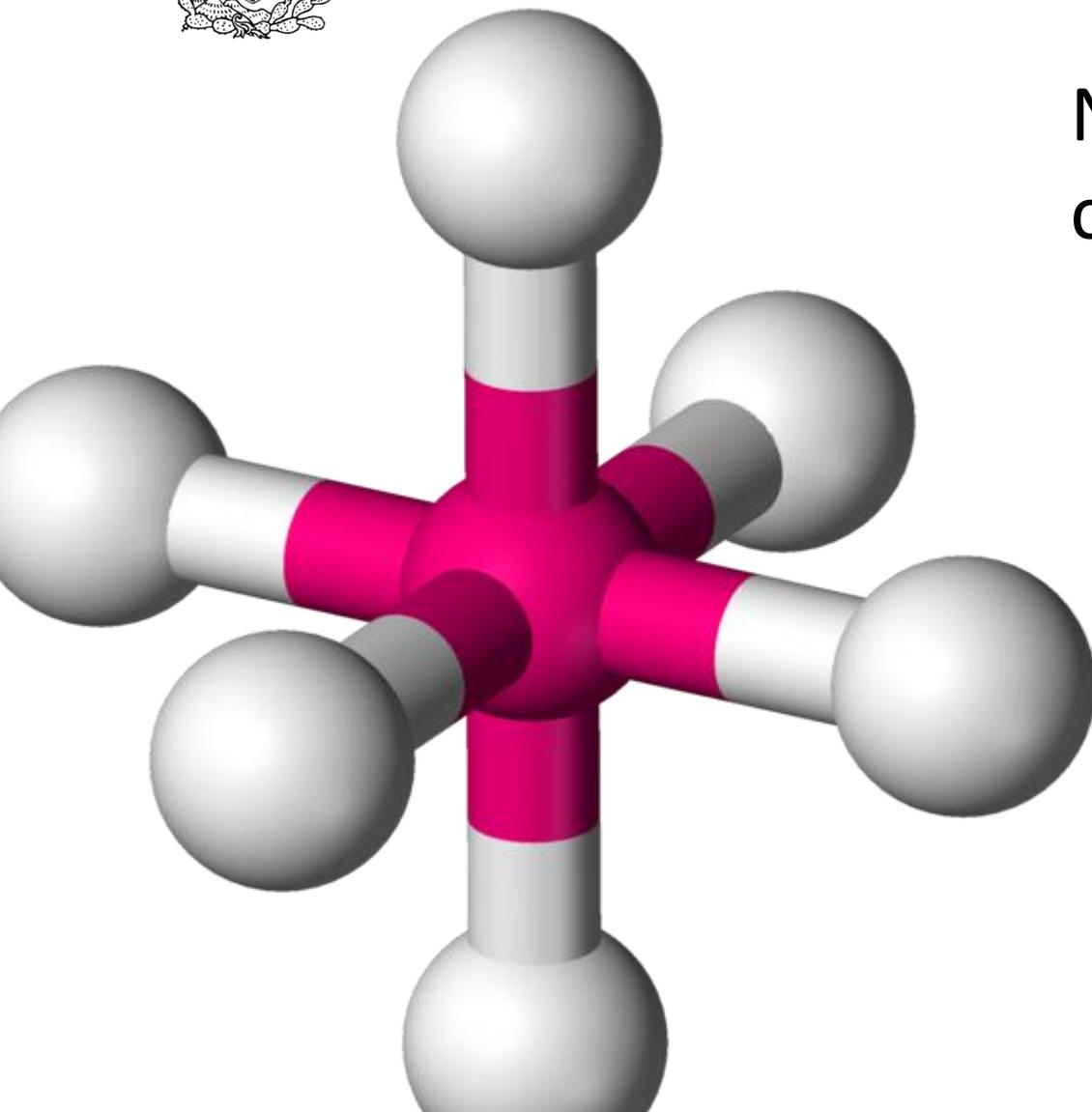
Teoría de Campo Cristalino





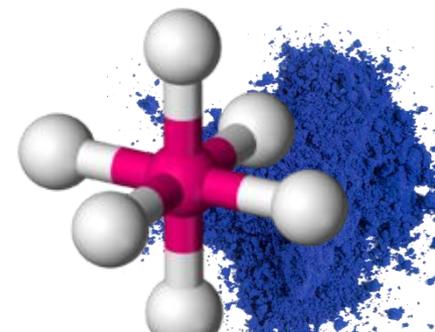
Octaedro

Número de
coordinación 6



$$\overline{d_{x^2-y^2}} \quad \overline{d_{z^2}}$$

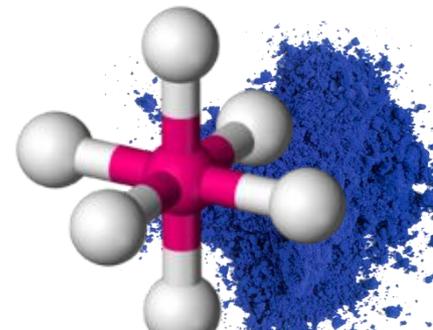
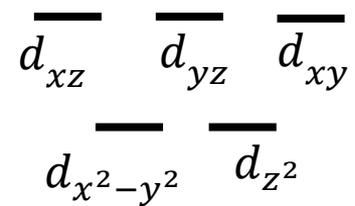
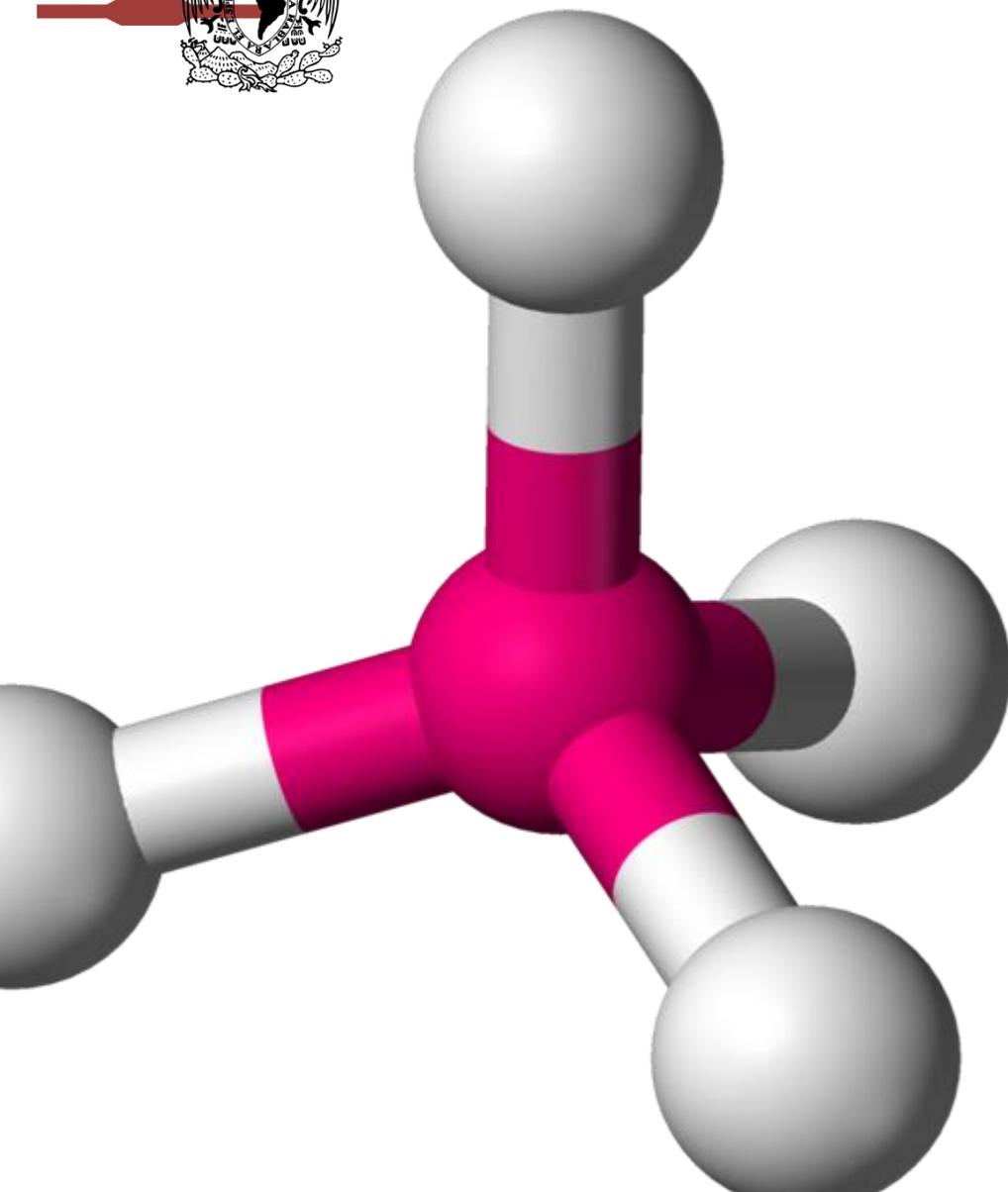
$$\overline{d_{xz}} \quad \overline{d_{yz}} \quad \overline{d_{xy}}$$





Tetraedro

Número de
coordinación 4

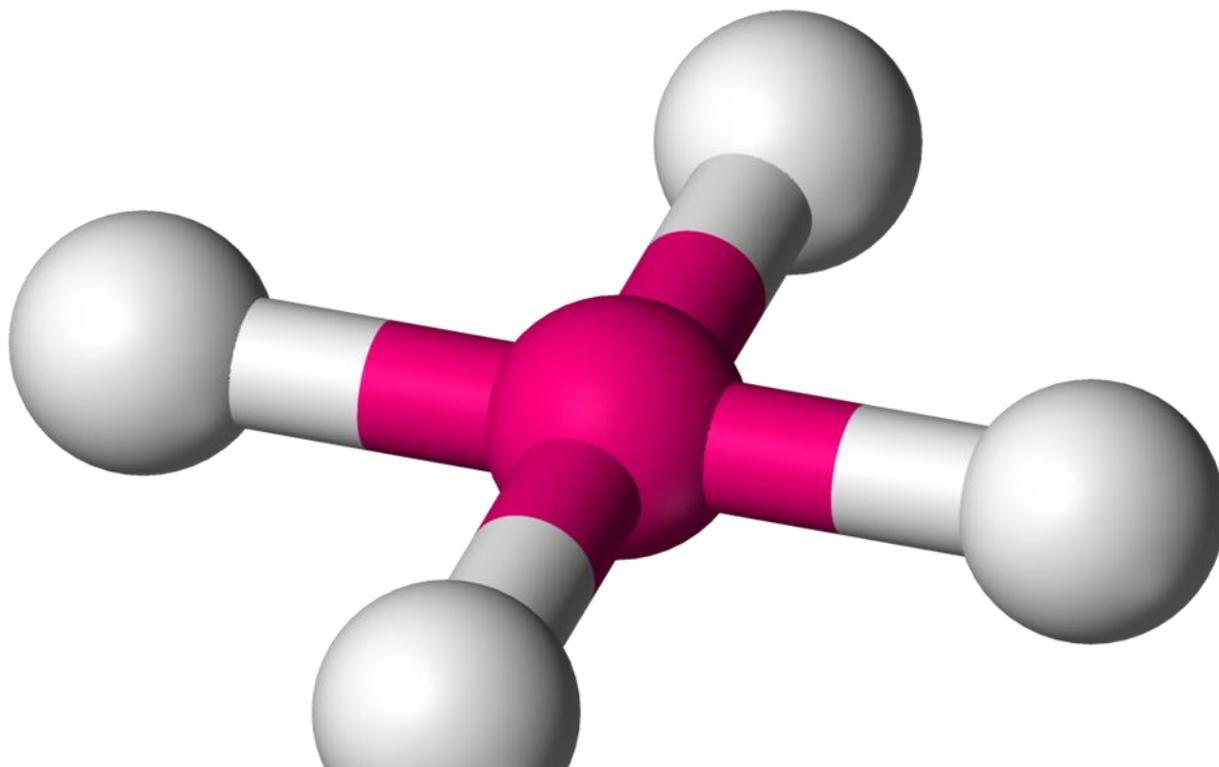




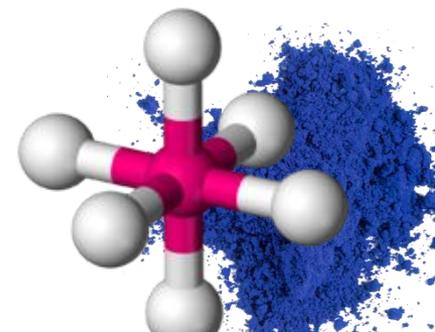
Cuadrado

Número de coordinación; 4

$$\overline{d_{x^2-y^2}}$$



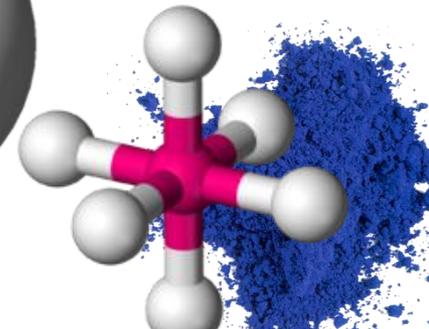
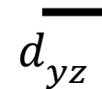
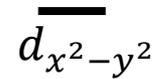
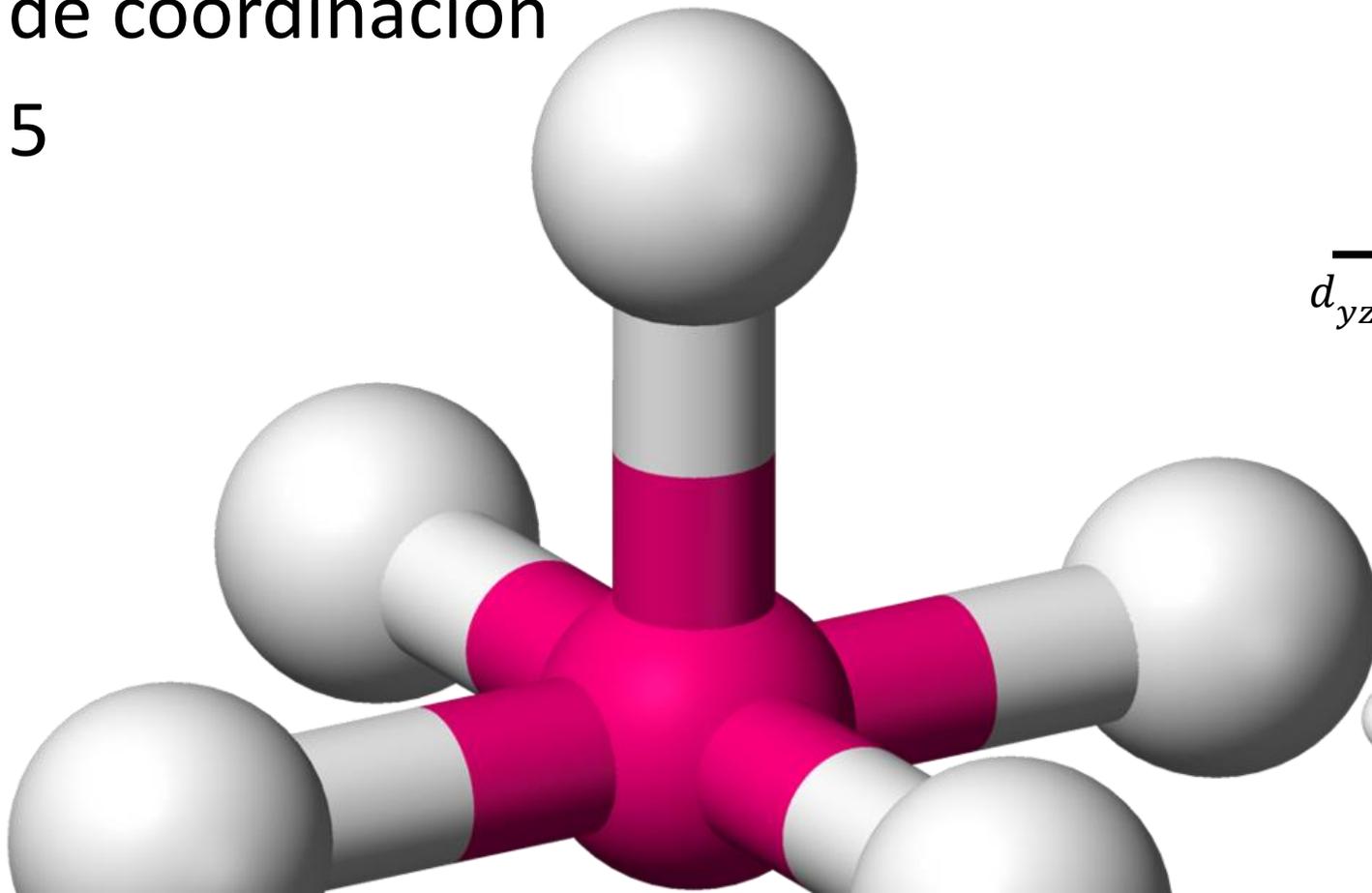
$$\begin{array}{c} \overline{d_{xz}} \\ \overline{d_{z^2}} \\ \overline{d_{yz}} \quad \overline{d_{xy}} \end{array}$$





Pirámide de base cuadrada

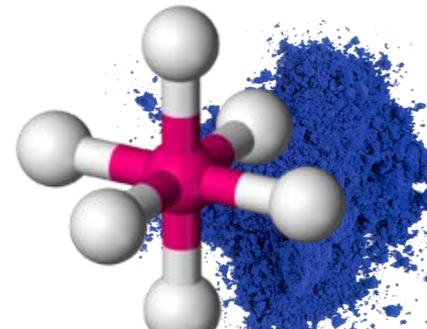
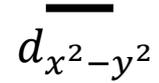
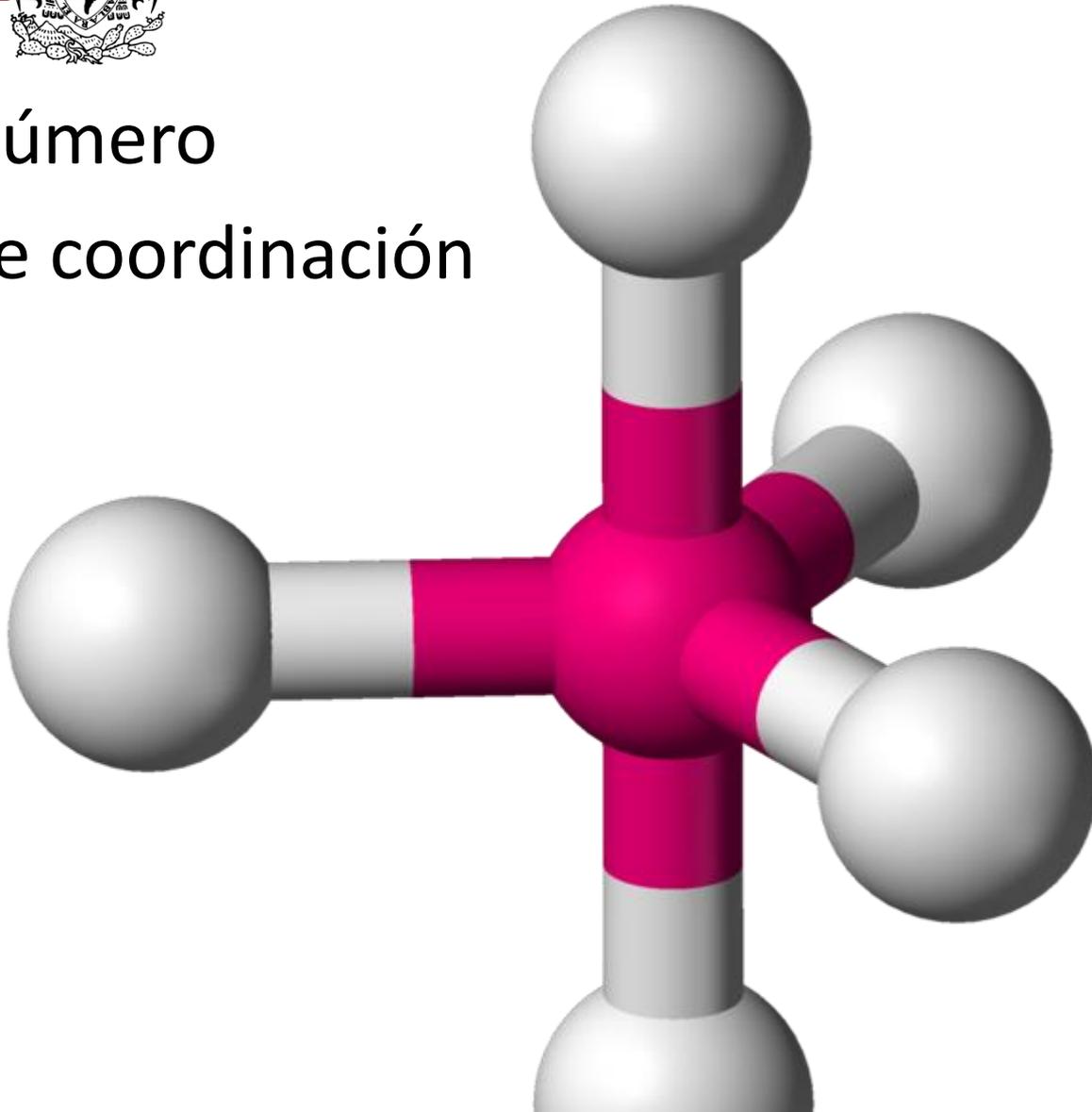
Número
de coordinación
5

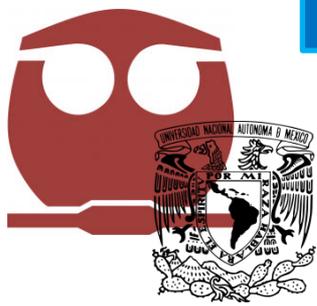




Bipiramide de base trigonal

Número
de coordinación
5





Propiedades ópticas – UV-Visible

$\lambda_{\text{max}} = 630 \text{ nm}$

Visible Spectrum

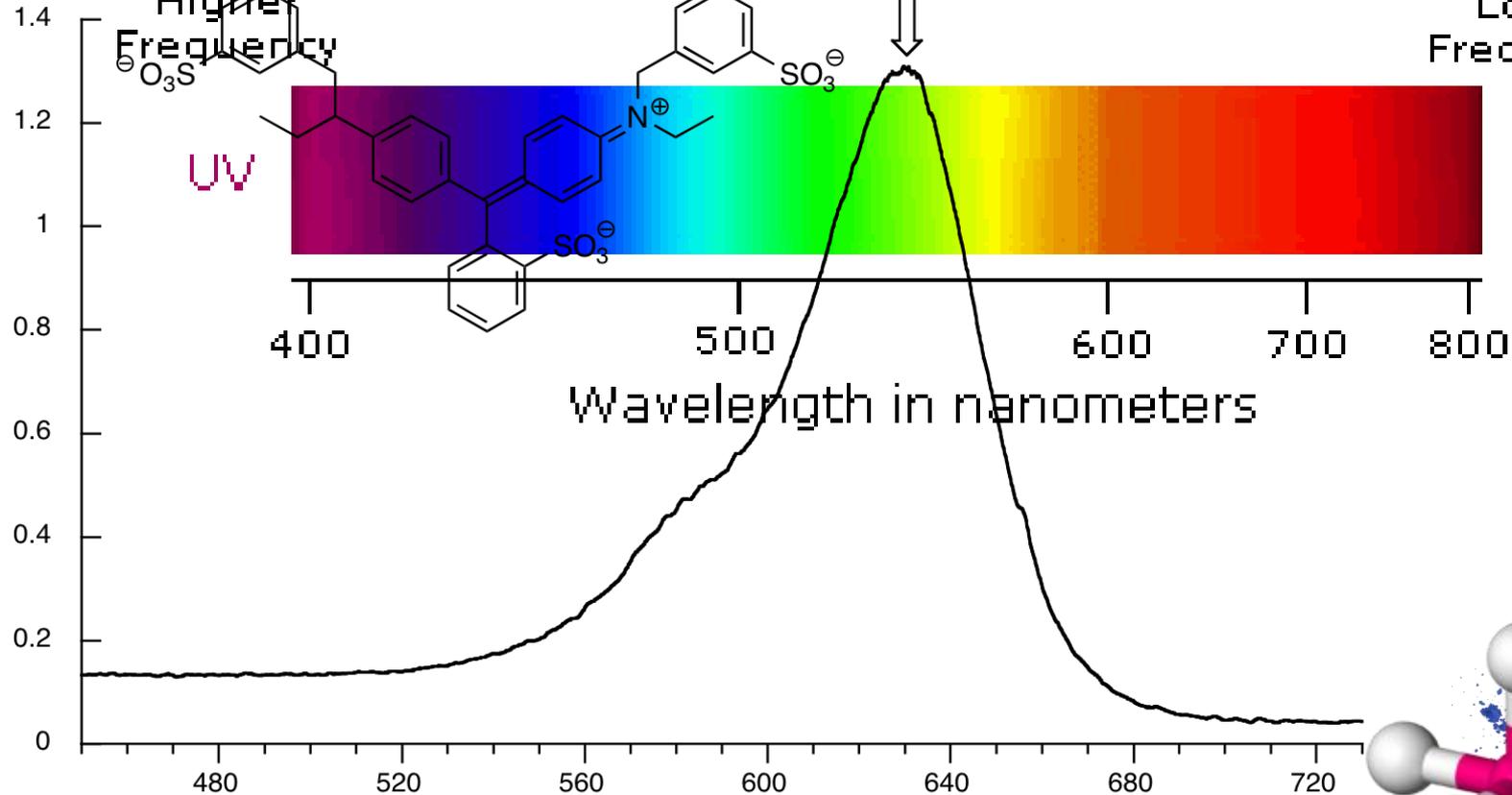
Higher Frequency

Lower Frequency

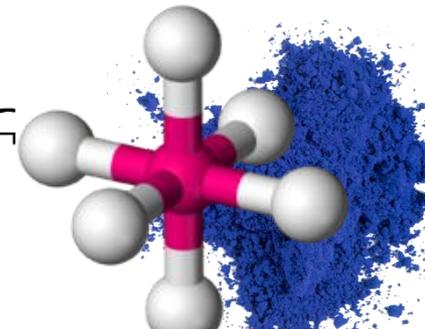
UV

IR

Absorbance

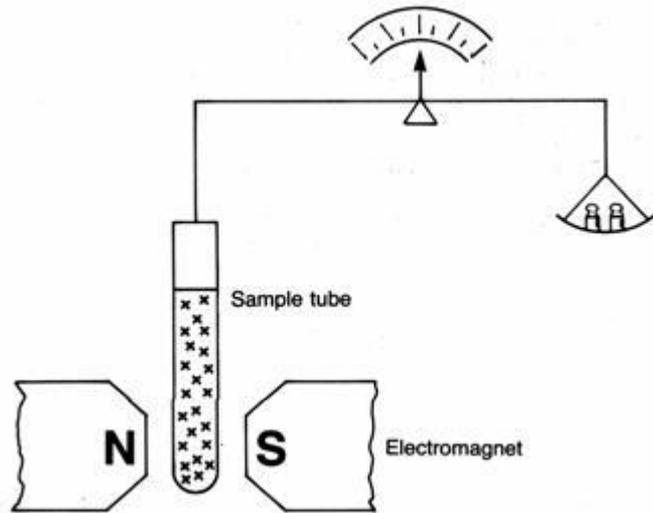


Wavelength (nm)

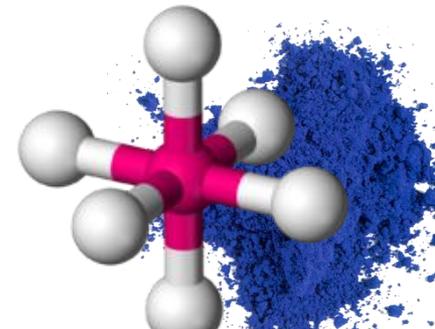




Susceptibilidad magnética

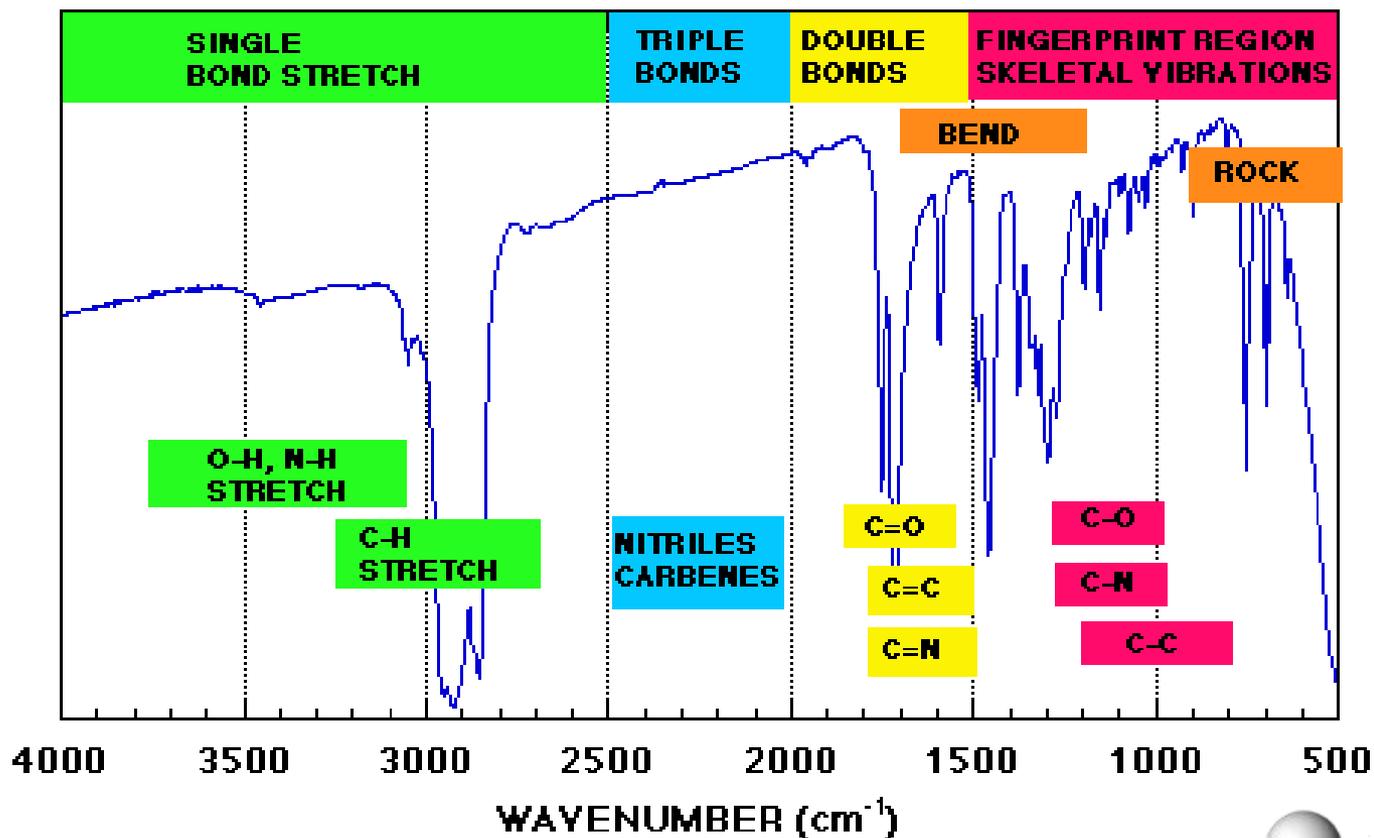


Electrones desapareados

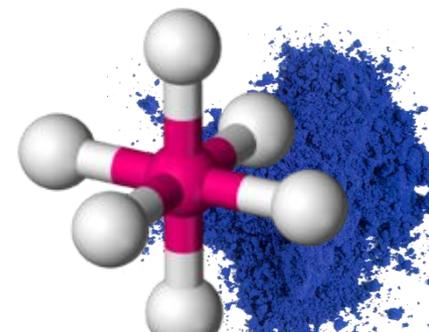




Espectroscopía Infrarroja

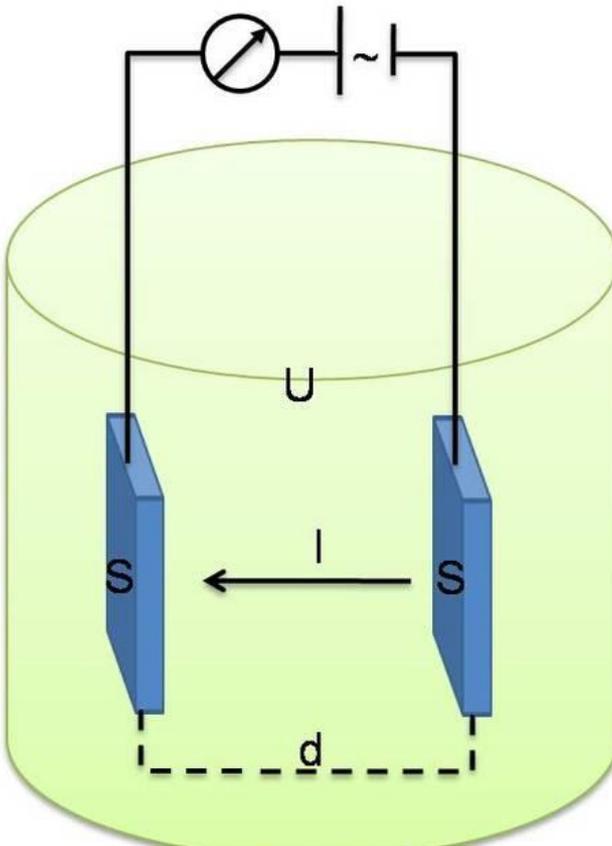


Estados Vibracionales
Grupos funcionales



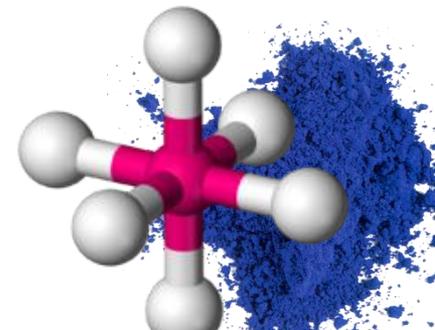


Conductividad



d – distancia entre electrodos
 S – Área del electrodo
 U – Voltaje aplicado
 K – Constante de la celda
 I – Intensidad generada

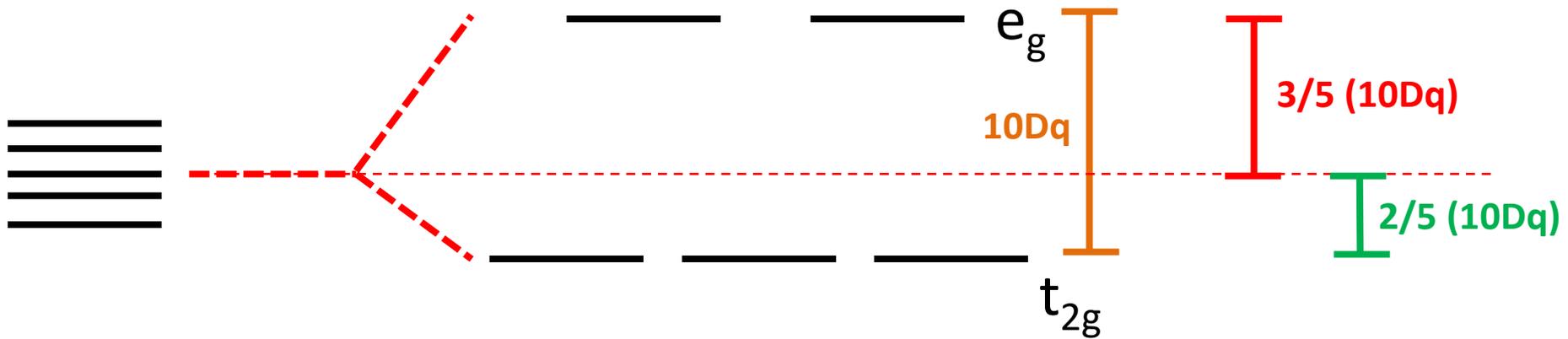
Especies iónicas



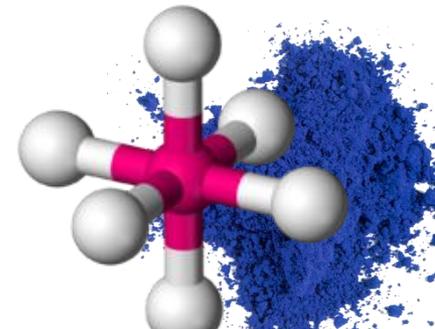


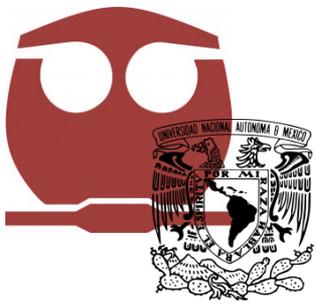
Estabilidad de los complejos

Energía de Estabilización de Campo Cristalino en un octaedro



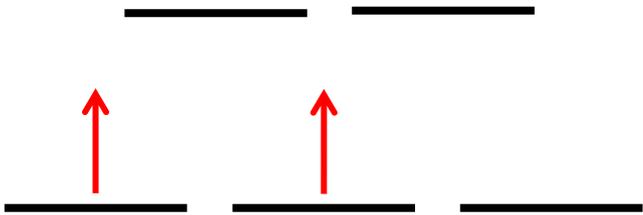
$$EECC = (\#electrones\ en\ e_g * 6) - (\#electrones\ en\ t_{2g} * 4)$$





Entre un V(III) y un Ni(III) ¿Qué compuesto es más estable?

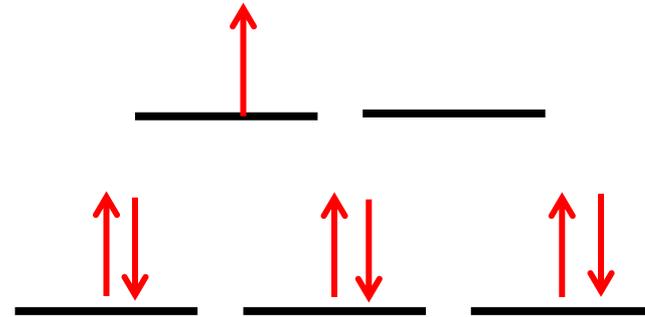
V(III) – d^2



$$EECC = (0 \cdot 6) - (2 \cdot 4)$$

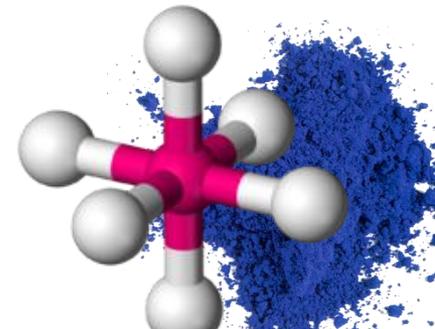
$$EECC = -8$$

Ni(III) – d^7



$$EECC = (1 \cdot 6) - (6 \cdot 4)$$

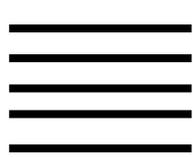
$$EECC = -18$$



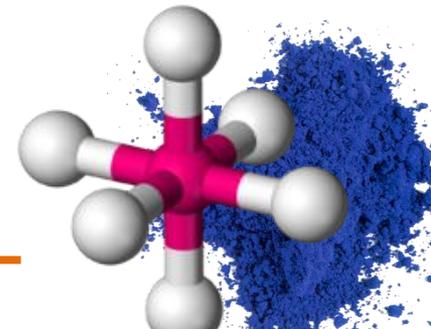
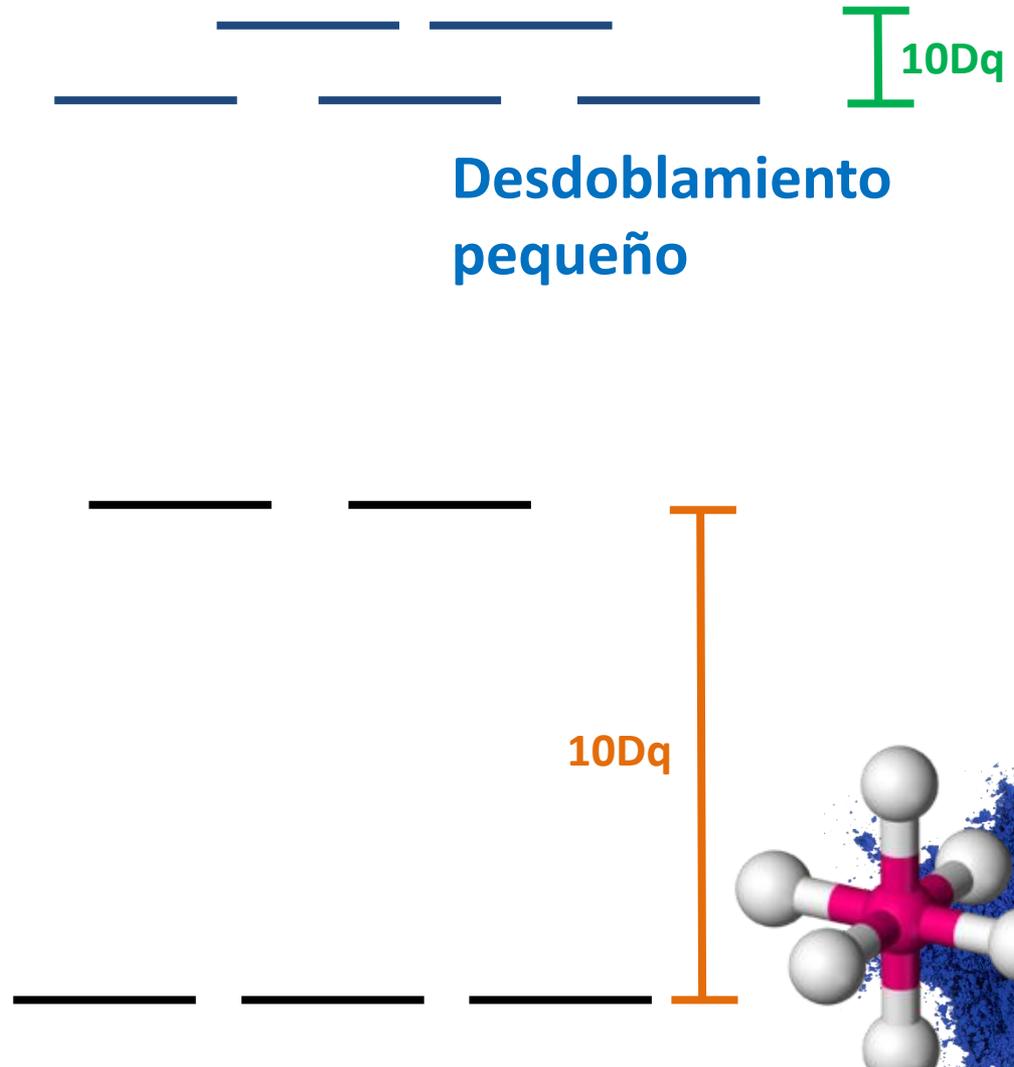


Desdoblamiento del campo

Ligantes



Desdoblamiento
grande

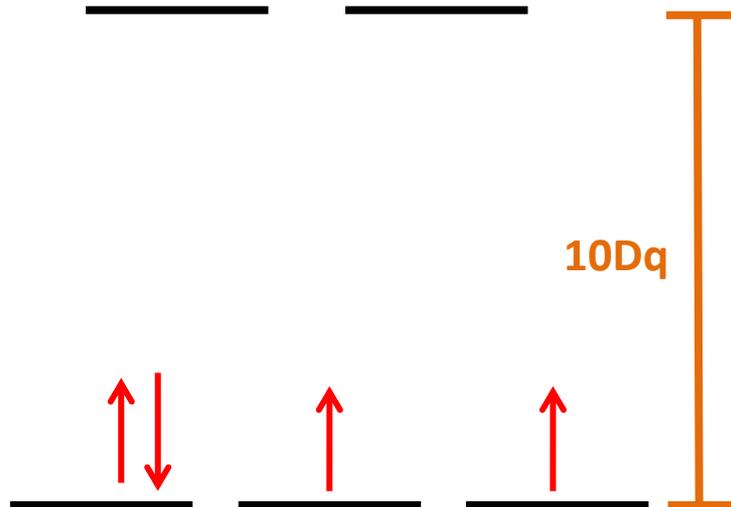




Desdoblamiento del campo para un d^4

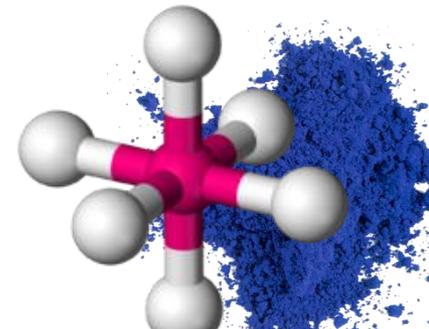
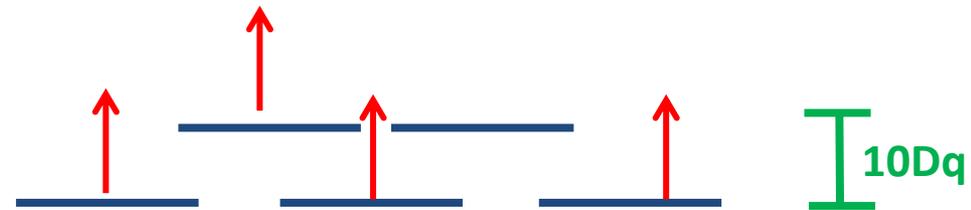
2 electrones
desapareados

Compuesto de campo
fuerte



4 electrones
desapareados

Compuesto de campo
débil



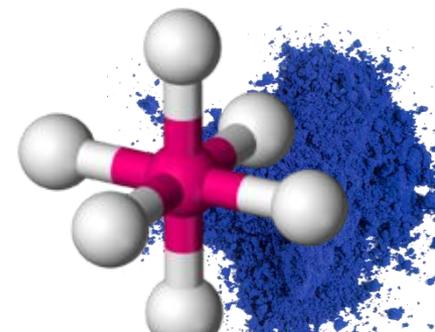


Serie Espectroquímica

Es de origen empírico.



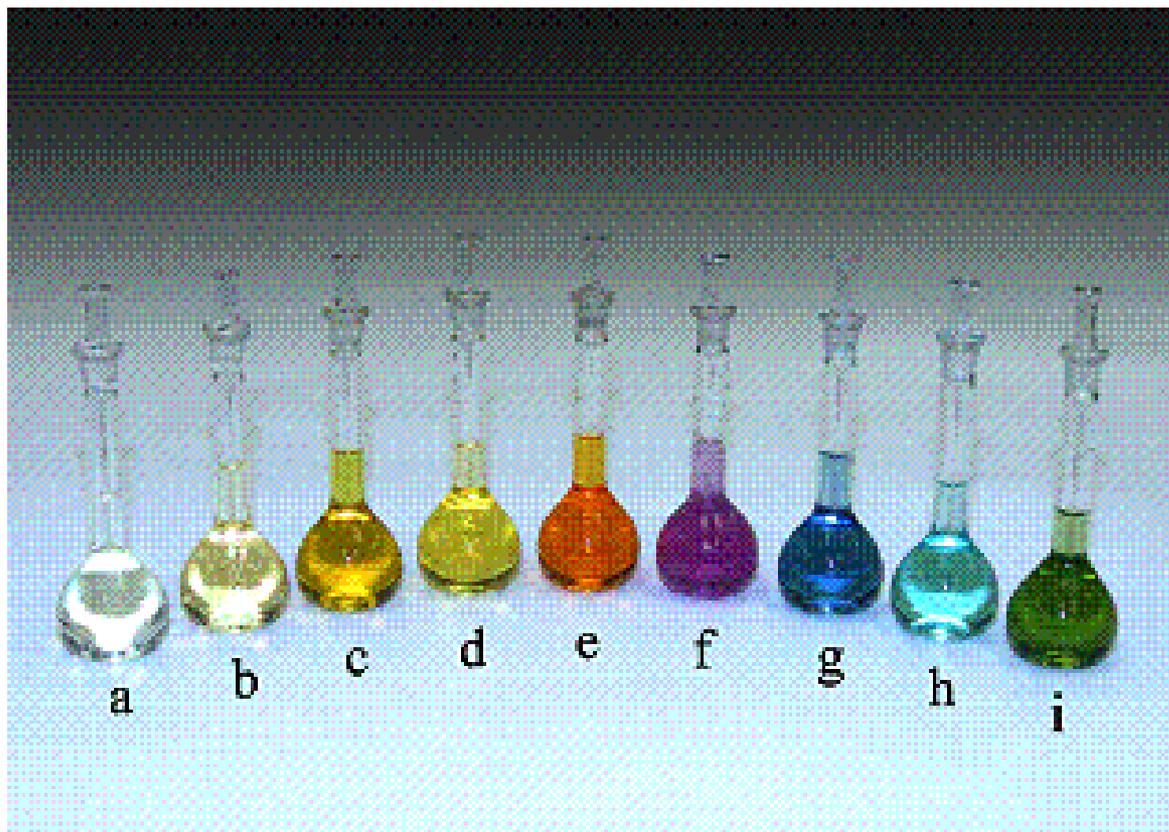
$I^- < Br^- < S^{2-} < SCN^- < Cl^- < NO_3^- < N_3^- <$
 $F^- < OH^- < C_2O_4^{2-} \approx H_2O < NCS^- < CH_3CN$
 $< py \text{ (piridina)} < NH_3 < en$
 $\text{(etilendiamina)} < bipy \text{ (2,2'-bipiridina)} <$
 $phen \text{ (1,10-fenantrolina)} < NO_2^- <$
 $PPh_3 < CN^- \approx CO$







Serie espectroquímica de los complejos de Co (III)



(a) CN^-

(b) NO_2^-

(c) Fen

(d) en

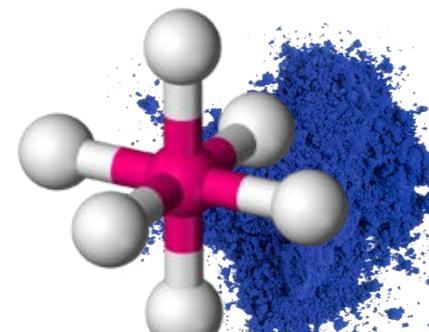
(e) NH_3

(f) gly

(g) H_2O

(h) ox^{2-}

(i) CO_3^{2-}



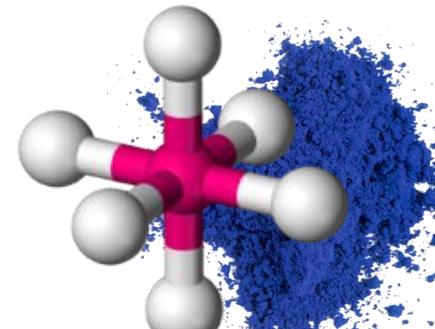


Efecto Quelato

1. A mayor número de dientes, mayor estabilidad



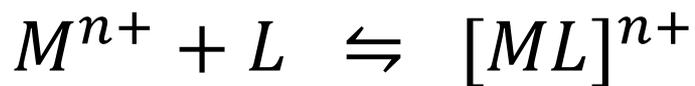
2. Anillos de 5 miembros son más estables que los de 6 miembros.



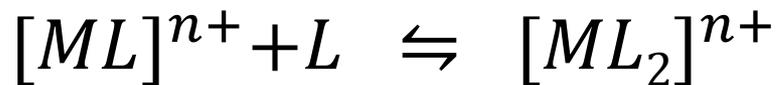


Constante de formación

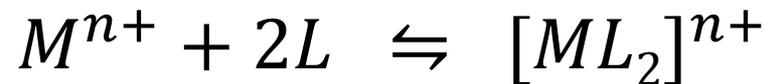
Equilibrio Químico



$$K_f = \frac{[[ML]^{n+}]}{[M^{n+}][L]}$$



$$K_{f2} = \frac{[[ML_2]^{n+}]}{[ML^{n+}][L]}$$



$$\beta_2 = K_f * K_{f2} = \frac{[[ML]^{n+}]}{[M^{n+}][L]}$$



Equilibrios parásitos

Favorece la corrosión, en equilibrios REDOX



Pt

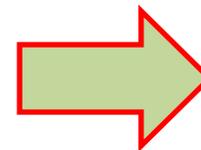
+ HNO₃



+ HCl

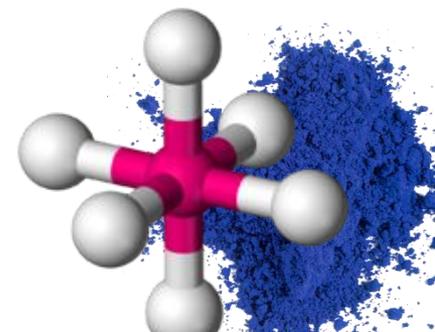
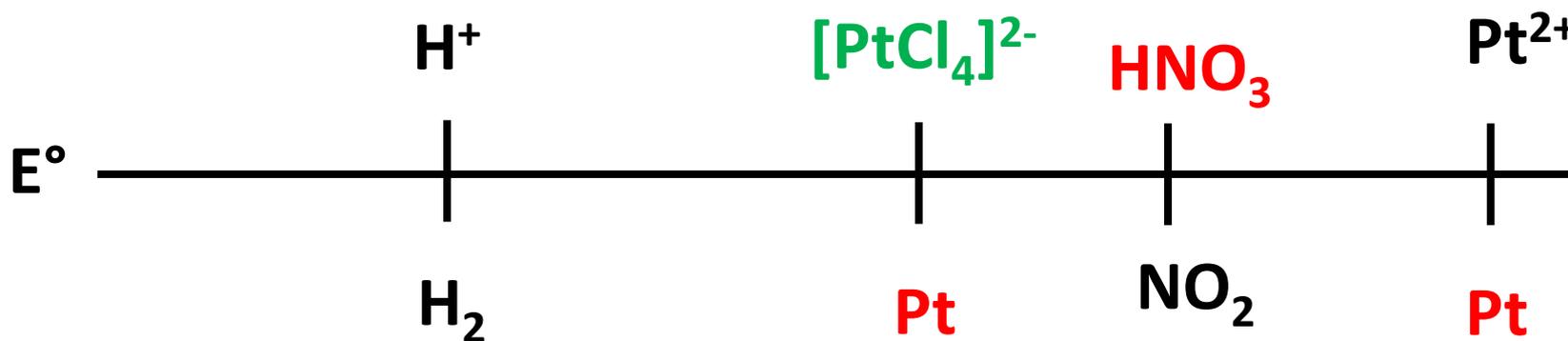


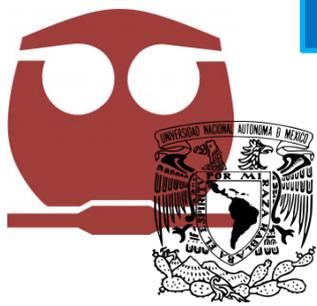
+ HCl/HNO₃





Equilibrios parásitos





Cinética de las reacciones

Efecto Trans

La sustitución de los ligandos es selectiva a la posición de los mismos.

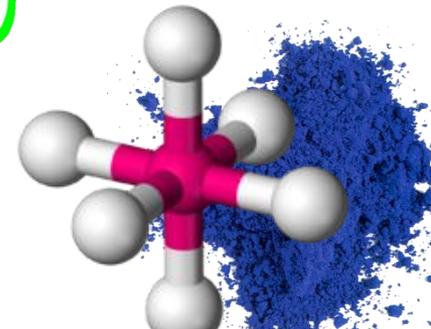
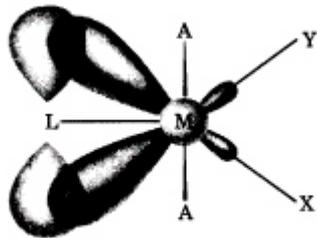
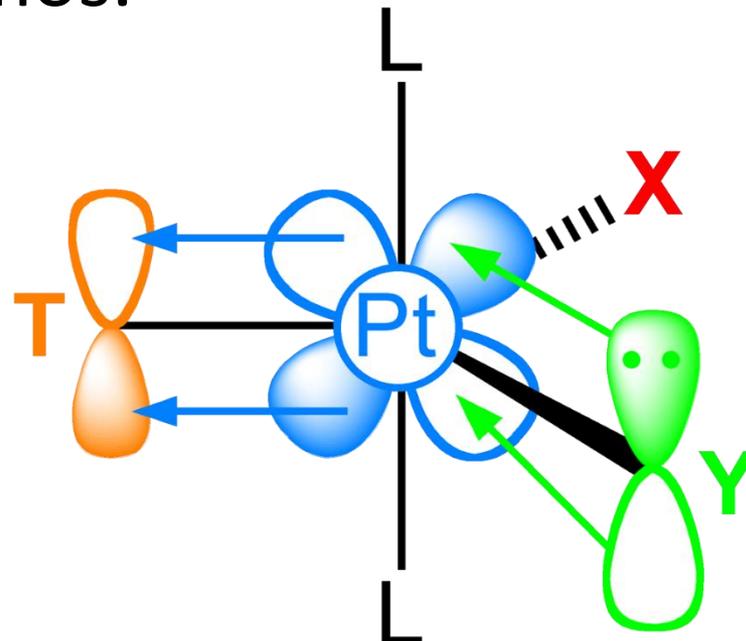


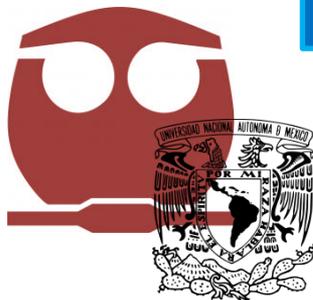
Figura 6-9 Complejo activado bpt 5-coordinado postulado para la reacción de Y con $\text{trans-Ma}_2\text{LX}$ en la que se desplaza X.

¿DUDAS?



EJEMPLOS DE COMPUESTOS DE COORDINACIÓN

ALGUNAS APLICACIONES



Bloque D

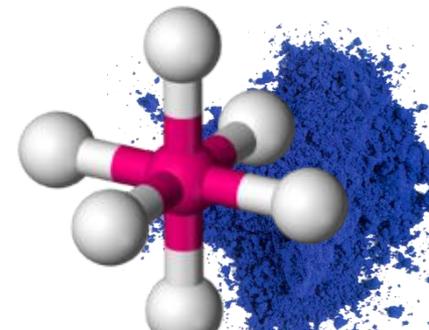
1 IA New Original		Alcalinos	Alcalinotérreos	Solida														18 VIIIA
1	H 1.0078	21 Sc Escandio 44.955910	22 Ti Titanio 47.867	23 V Vanadio 50.9415	24 Cr Cromo 51.9961	25 Mn Manganeso 54.938049	26 Fe Hierro 55.8457	27 Co Cobalto 58.933200	28 Ni Níquel 58.6934	29 Cu Cobre 63.546	30 Zn Zinc 65.409							
2	Li 6.941																	
3	Na 22.989																	
4	K 39.098	39 Y Itrio 88.90585	40 Zr Circonio 91.224	41 Nb Niobio 92.90638	42 Mo Molibdeno 95.94	43 Tc Tecnecio (98)	44 Ru Rutenio 101.07	45 Rh Rodio 102.90550	46 Pd Paladio 106.42	47 Ag Plata 107.8682	48 Cd Cadmio 112.411							
5	Rb 85.468																	
6	Cs 132.905	57 to 71	72 Hf Hafnio 178.49	73 Ta Tántalo 180.9479	74 W Wolframio 183.84	75 Re Renio 186.207	76 Os Osmio 190.23	77 Ir Iridio 192.217	78 Pt Platino 195.078	79 Au Oro 196.96655	80 Hg Mercurio 200.59							
7	Fr 223																	

Atomic masses in parentheses are those of the most stable or common isotope.

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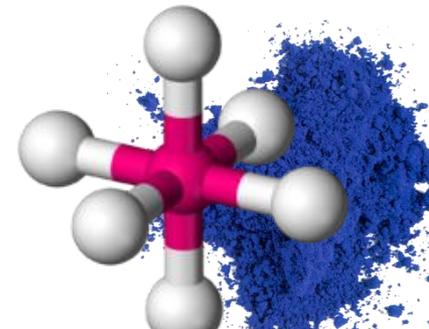
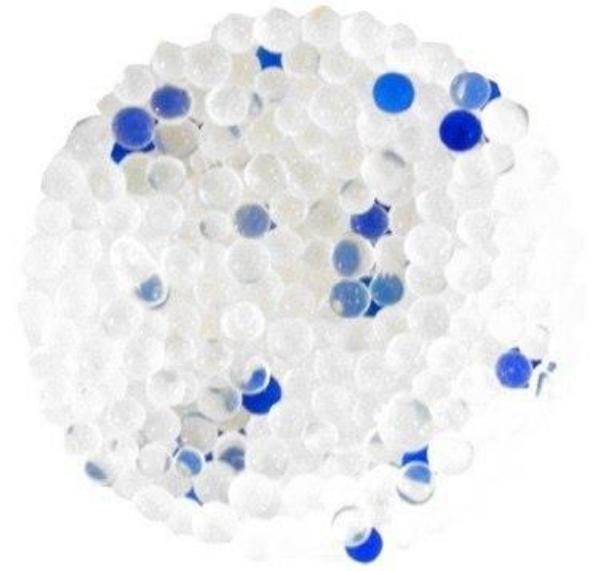
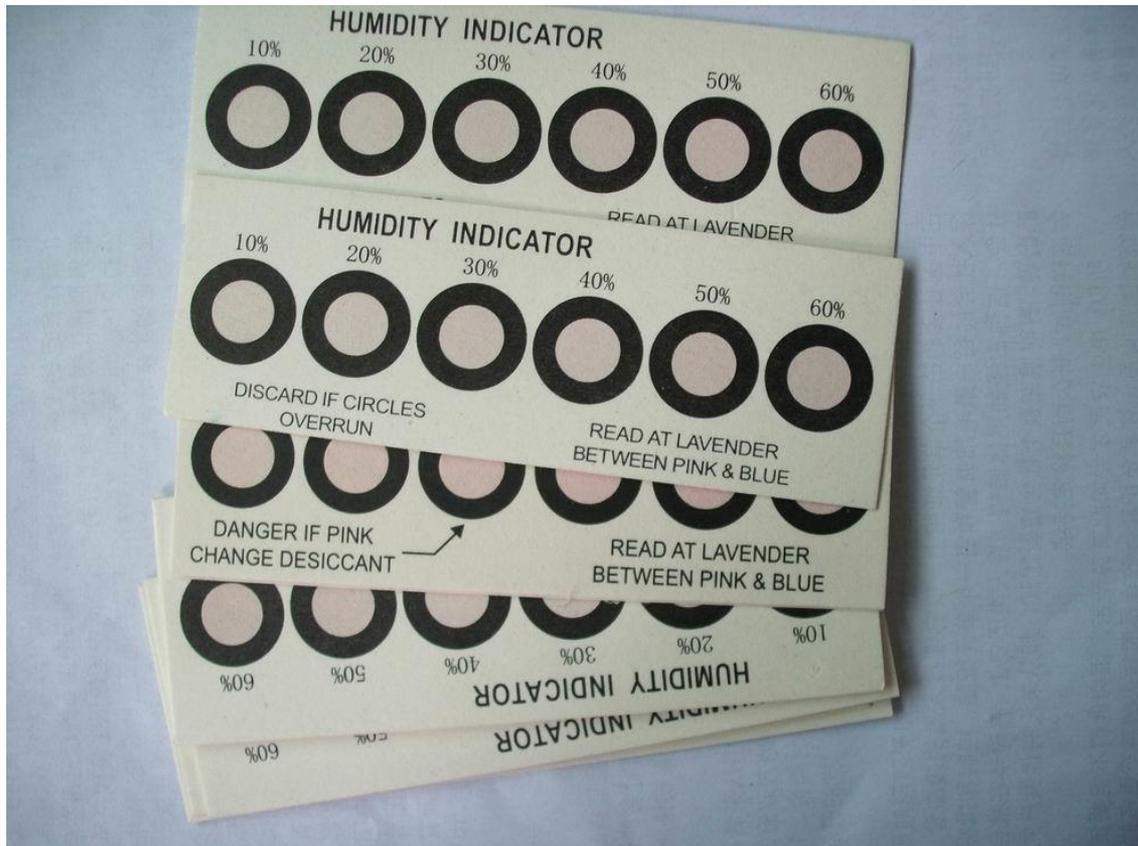
Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.

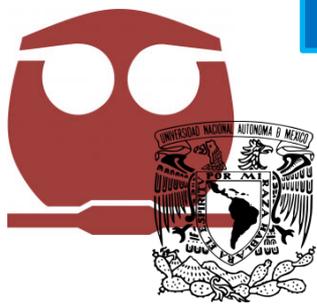
57 La Lantano 138.9055	58 Ce Cerio 140.116	59 Pr Praseodimio 140.90765	60 Nd Neodimio 144.24	61 Pm Prometio (145)	62 Sm Samario 150.36	63 Eu Europio 151.964	64 Gd Gadolinio 157.25	65 Tb Terbio 158.92534	66 Dy Disprosio 162.500	67 Ho Holmio 164.93032	68 Er Erbio 167.259	69 Tm Tulio 168.93421	70 Yb Iterbio 173.04	71 Lu Lutecio 174.967
89 Ac Actinio (227)	90 Th Torio 232.0381	91 Pa Protactinio 231.03688	92 U Uranio 238.02891	93 Np Neptunio (237)	94 Pu Plutonio (244)	95 Am Americio (243)	96 Cm Curio (247)	97 Bk Berkelio (247)	98 Cf Californio (251)	99 Es Einstenio (252)	100 Fm Fermio (257)	101 Md Mendelevio (258)	102 No Nobelio (259)	103 Lr Lawrencio (262)





Detectores de humedad - Co

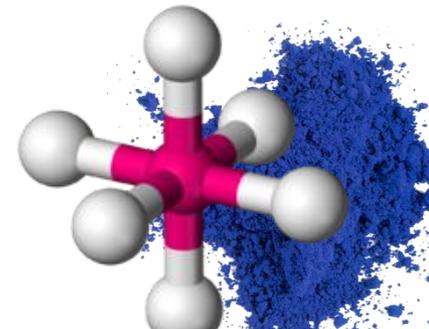
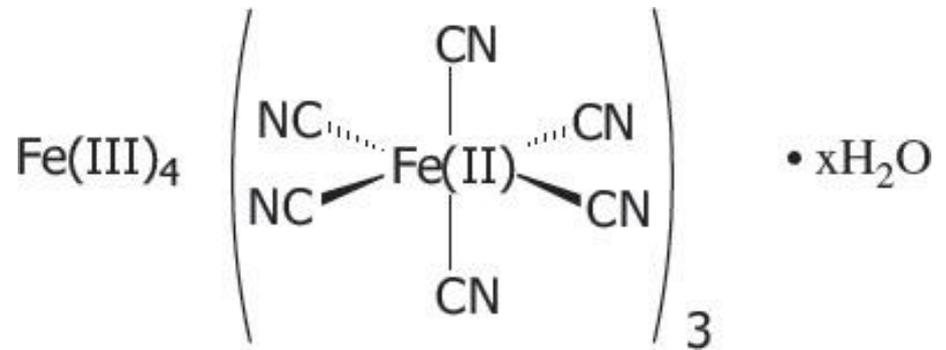


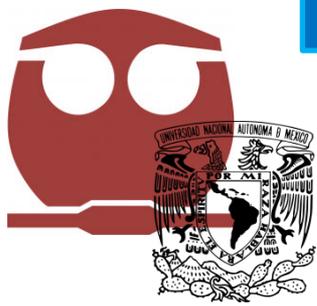


Pinturas

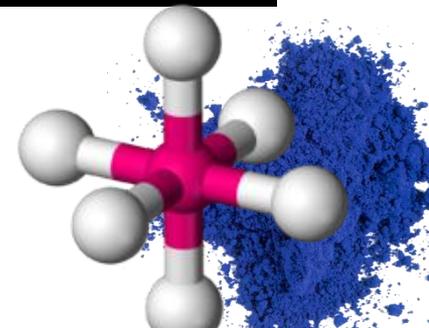
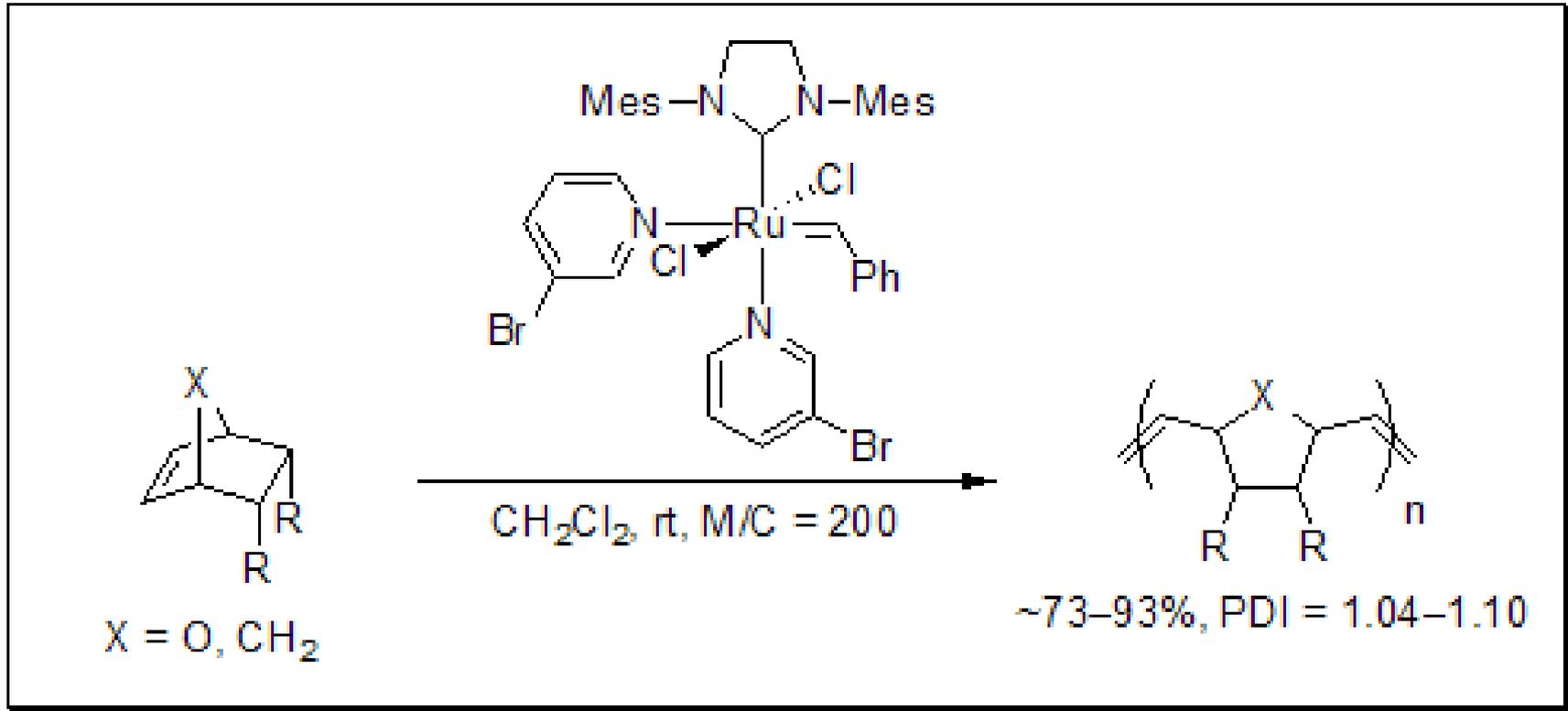


Azul de Prusia





Catalizador de Polimerización

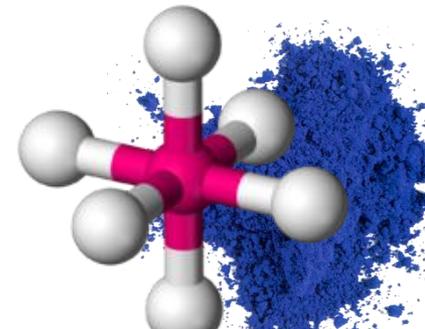
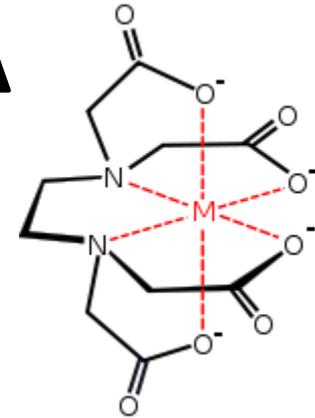


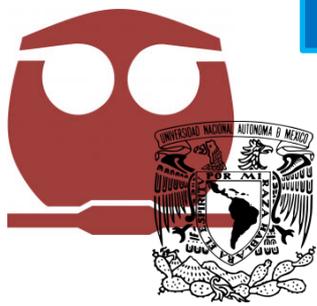


Dureza y tratamiento del Agua

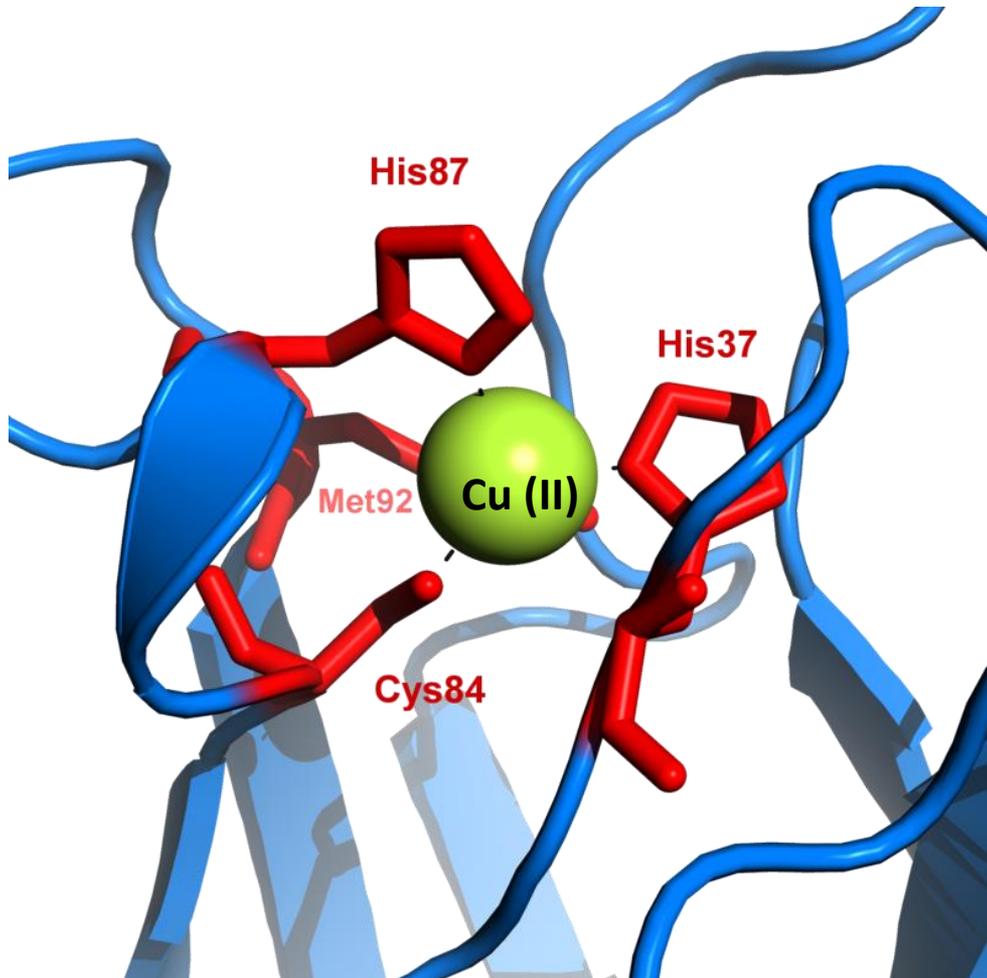


EDTA

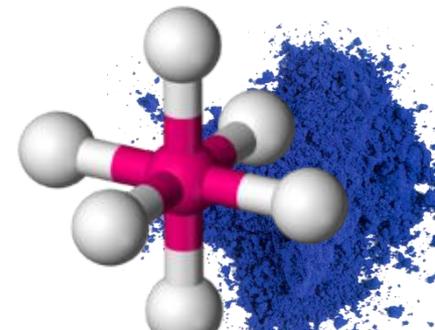




Compuestos de coordinación en seres vivos



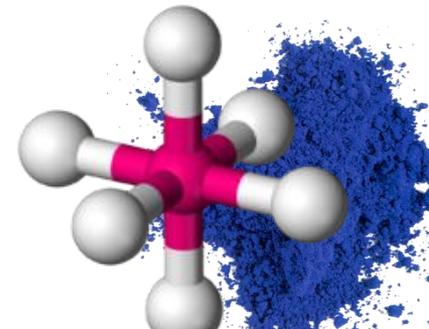
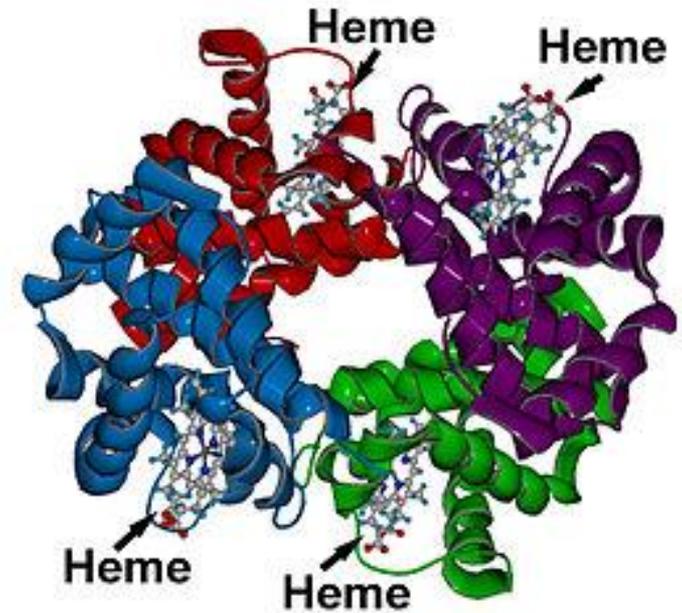
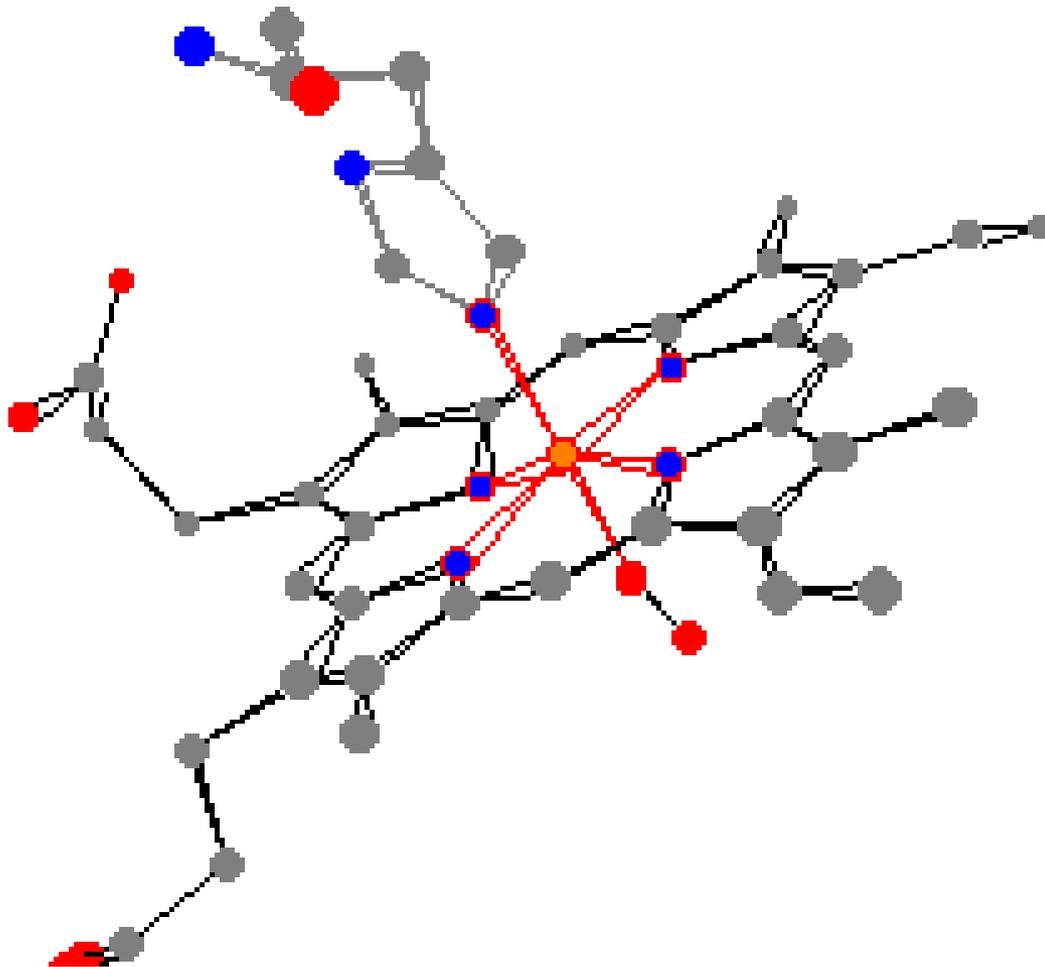
**Laccasa –
Reacciones REDOX**

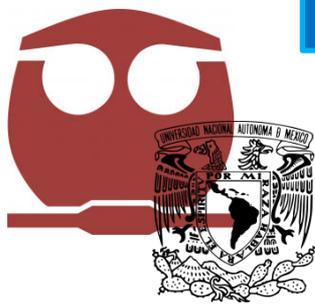




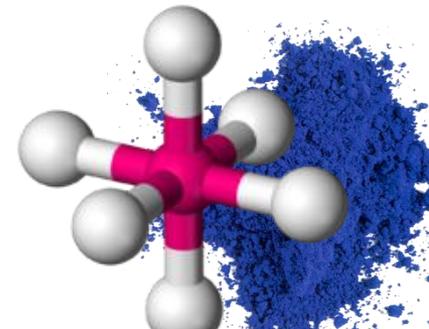
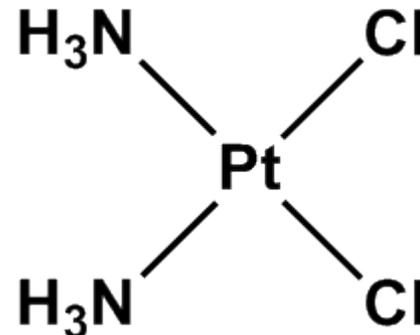
Función enzimática

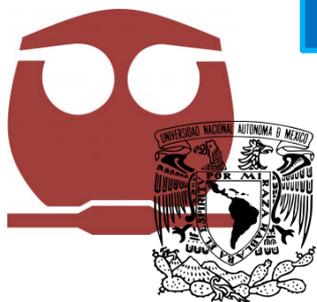
Grupo Hemo [Fe (II)]





Tratamiento del cancer

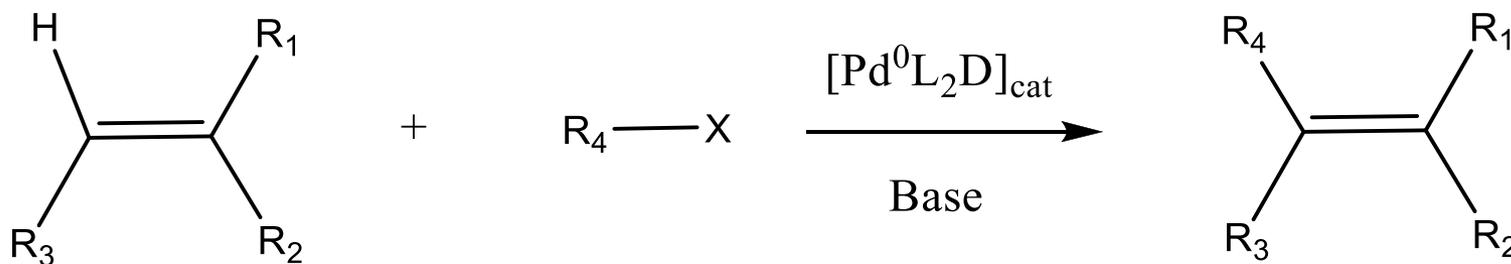




Reacción de Heck

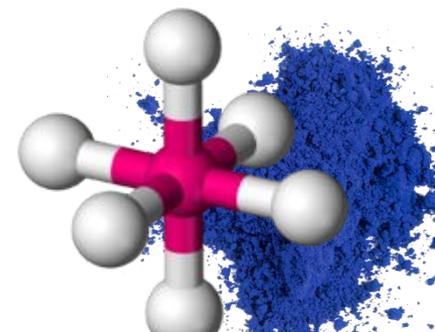
PREMIO NOBEL 2010

- Acoplamiento carbono-carbono.
- Se utiliza Pd, como catalizador.

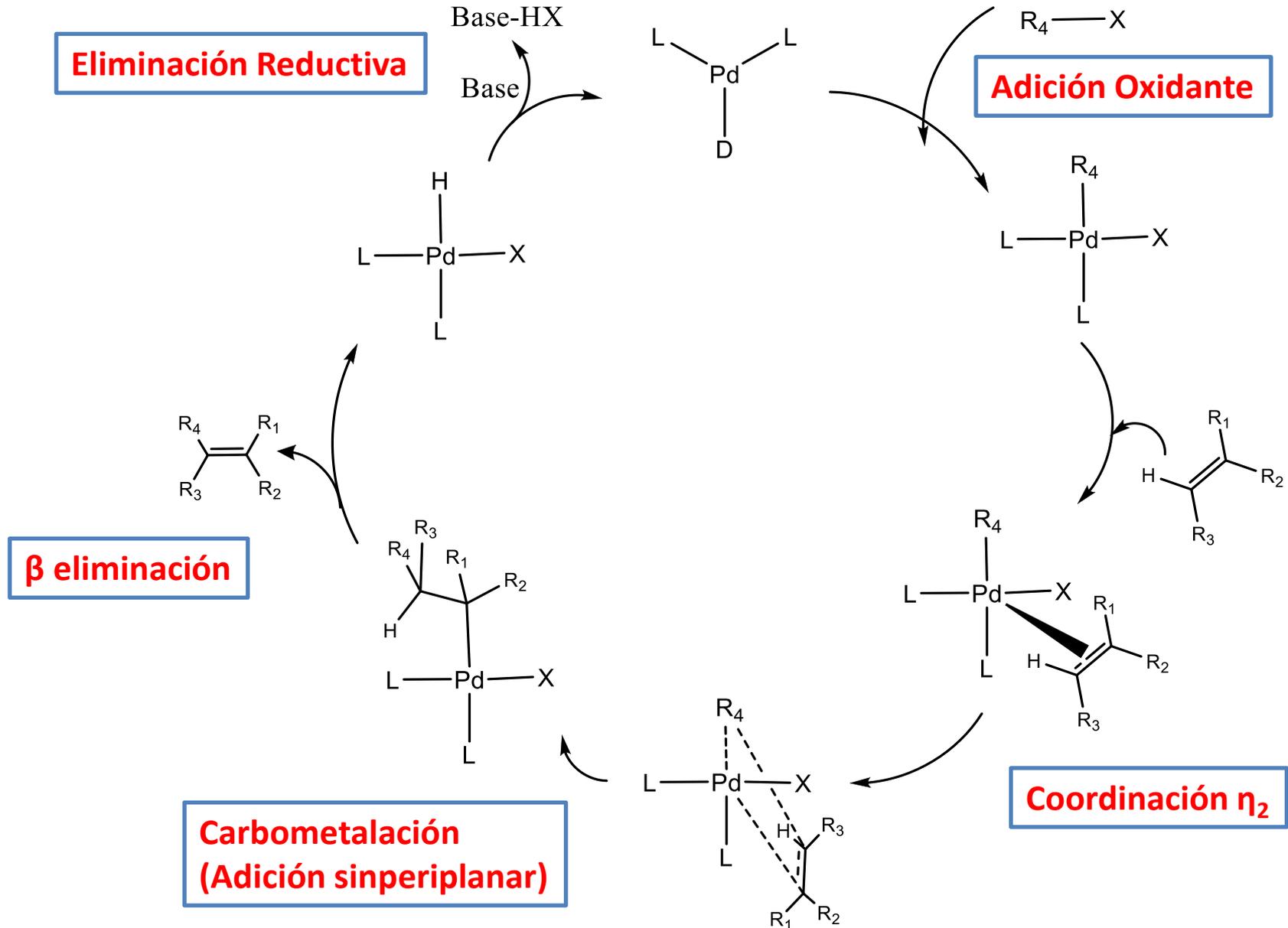


X = I, OTf, Br, Cl

R₄ = aril, bencil, vinil



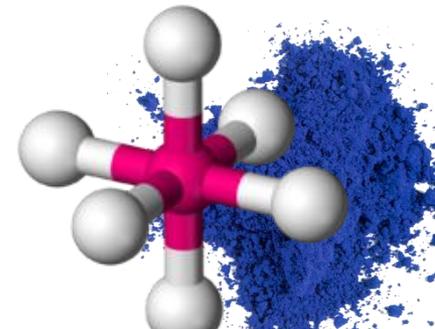
Mecanismo de Reacción propuesto





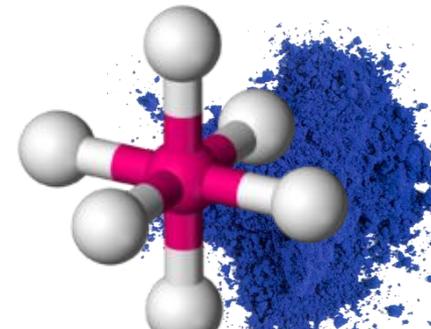
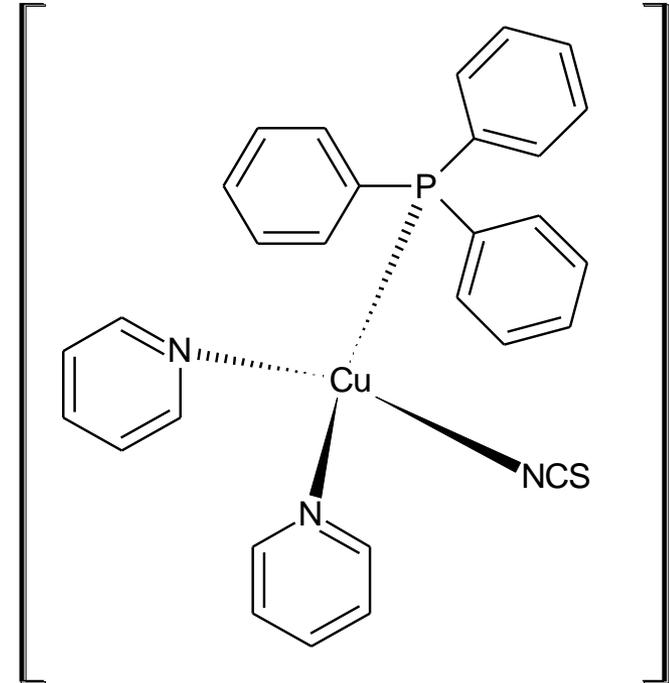
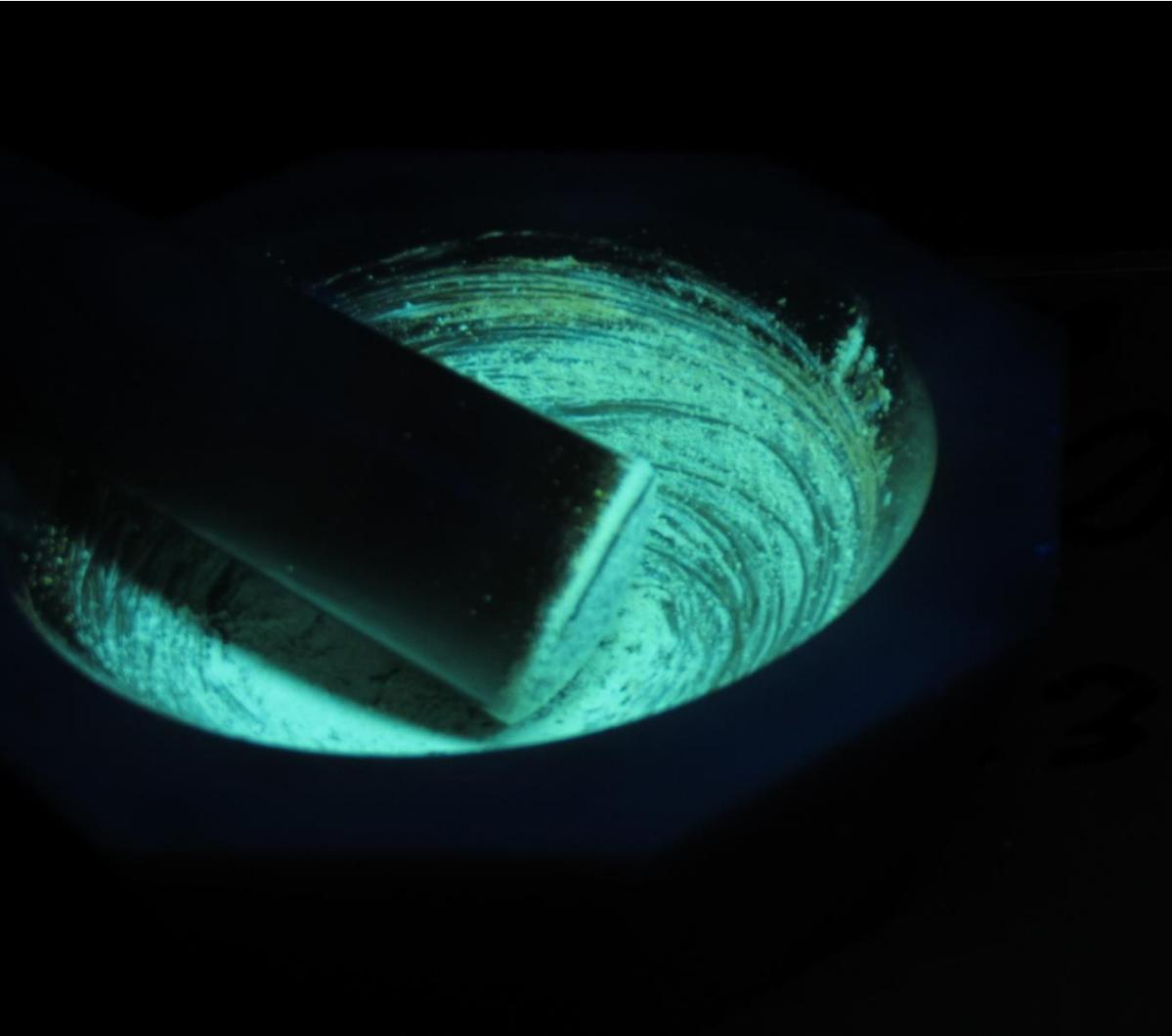
Posibles aplicaciones

- Sensores magnéticos (spin crossover)





Compuesto triboluminiscente



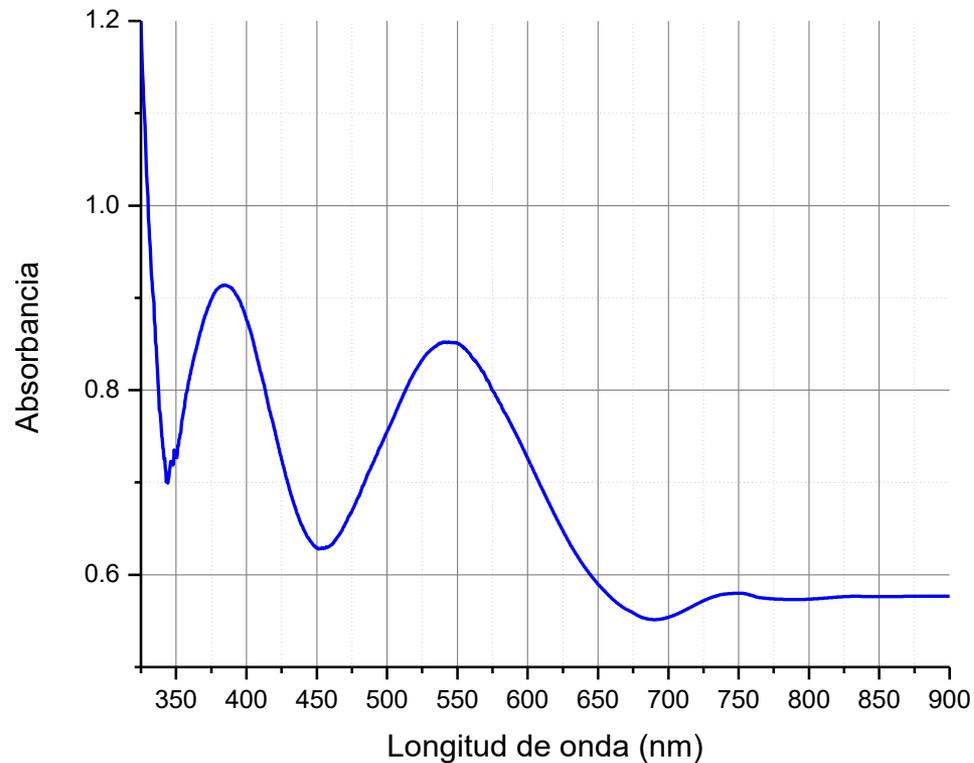
Ejercicio

¿Cuál será el número de electrones desapareados para los siguientes complejos?

- Hexacianoferrato (II) de potasio
- $[\text{Zn}(\text{NH}_3)_4](\text{NO}_3)_2$
- Tetracloroplatinato de tetrabutilamonio
- $[\text{Rh}(\text{bpy})(\text{PPh}_3)_2]$
 - » Tip – El platino (II) tiende a formar complejos cuadrados. El Zinc puede adoptar muchas geometrías, sin embargo se le encuentra como tetraedro.

Ejercicio II

- De que color esperas observar para el complejo de $[\text{Co}(\text{gly})_3]$



Ejercicio III

Dibuja los siguientes complejos y encuentra las diferentes formas en las que se pueden acomodar los ligantes.



» Tip: Existen 2 isómeros [cis y trans]



» Tip: Existen 2 isómeros [mer y fac]



» Tip: Existen 2 isómeros [delta (Δ) y lambda (Λ)]