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uOttawa

CHM 2353

Midterm 2

9-Nov-2012

Family name: _____

Given name: _____

Student number _____

Midterm: 1h : 15min

Question	1	2	3	4	5	6	7	8	Total
Points	10	10	5	5	5	5	10	10	60
Remarks									

Please keep your work covered and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the University.
A periodic table, point group chart is given at the end of the exam. You may rip these 2 pages off of the exam and use them to cover your work.

Please write the exam using a pen, you can use colorful pen however avoid red pens.

Traditional calculators and molecular models are allowed.

Please provide detailed explanation for your answers.

1) (*10 points*)

a) What type of isomerism can arise with ambident ligands? Give an example.

Linkage isomer, NCS^-

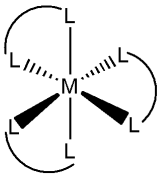
b) Explain the meaning of the terms monodentate, bidentate and tetradentate.

Monodentate ligands are Lewis bases that donate a single pair ("mono") of electrons to a metal atom.

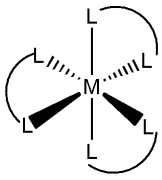
Bidentate ligands are Lewis bases that donate two pairs ("bi") of electrons to a metal atom. Bidentate ligands are often referred to as ***chelating ligands***

Tetradentate Describing a chelating ligand that has four groups that attach to a metal ion.

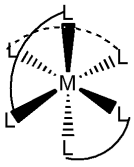
c) Draw both Λ and Δ isomers of the $[Ru(en)_3]^{2+}$ cation.



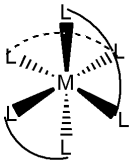
Λ



Δ



Λ



Δ

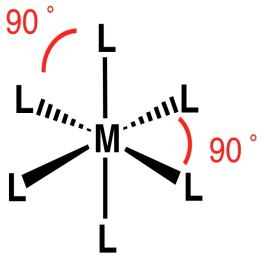
3-D arrangement is important.

d) The two compounds $[RuBr(NH_3)_5]Cl$ and $[RuCl(NH_3)_5]Br$ are what type of isomers?

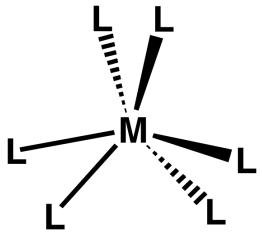
Ionization Isomerism

e) Sketch the two structures that describe most six coordinate complexes. Which one of these is rare?

Common octahedral:

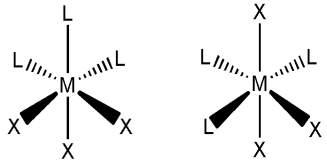


Rare: Trigonal prism:

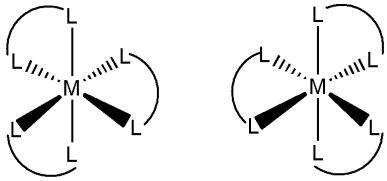


2) (*10 points*) For which of the following octahedral complexes are isomers possible? Draw all the isomers cleanly. $[FeCl(H_2O)_5]^{2+}$, $[Ir(Cl)_3(NH_3)_3]$, $[Ru(en)_3]^{2+}$, $[Co(Cl)_2(en)(NH_3)_2]^{+}$, $[W(CO)_4(py)_2]$

$[Ir(Cl)_3(NH3)_3]$: $[ML_3X_3]$: "fac" and "mer" isomers:



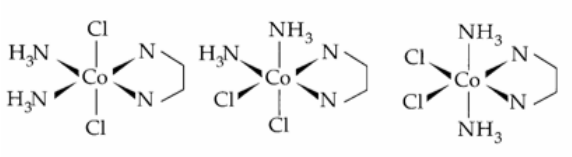
$[Ru(en)_3]^{2+}$: optical isomers :



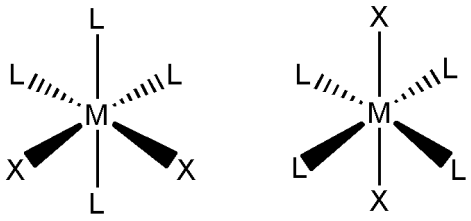
Λ Δ

$[Co(Cl)_2(en)(NH_3)_2]^{+}$:

There are three isomers. In one, the two Cl- ligands are *trans* to one another. In the other two, the two Clligands are *cis* to one another. The three isomers are shown below (the 1+ charge for each of these three isomers is not shown).



$[W(CO)_4(py)_2]$: $[ML_4X_2]$: cis and trans isomers:



3) (*5 points*) Assign oxidation numbers to the elements in

a) HI

H (+1); I (-1)

b) H_2S

H (+1); S(-2)

c) KH

H (-1); K(+1)

d) $[ReH_9]^{2-}$

H (-1); Re(+7)

e) H_2SO_4

H(+1); S(6); O(-2)

4) This does not count for midterm 2 as we have not seen chapter on H

(*5 points*) Describe three different common methods for the synthesis of H_2 and illustrate each one with balanced chemical equation.

Water gas reactions:

$$C\,(s) + H_2O\,(g) \longrightarrow CO\,(g) + H_2\,(g)$$

$$CO\,(g) + H_2O\,(g) \longrightarrow CO_2\,(g) + H_2\,(g)$$

The steam reformer process:

$$CH_4\,(g) + H_2O\,(g) \longrightarrow CO\,(g) + 3\,H_2\,(g)$$

All 3 methods involve reduction of gaseous H_2O (steam)

Reduction of acid by a metal:

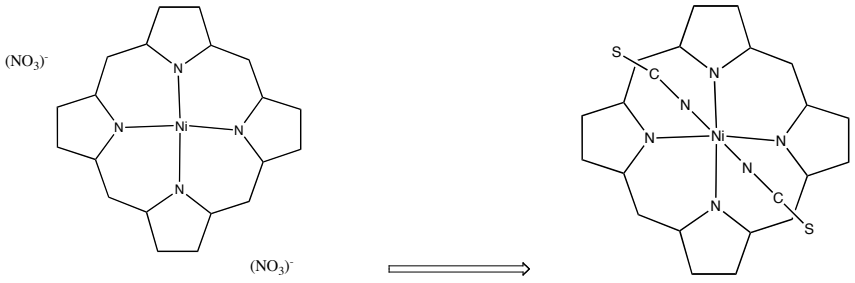
$$Zn\,(s) + 2\,HCl\,(aq) \rightleftharpoons ZnCl_2\,(aq) + H_2\,(g)\uparrow$$

Electrolysis of water (99.9% pure H_2):

$$H_2O\,(l) \rightleftharpoons H_2\,(g) + \tfrac{1}{2}\,O_2\,(g) \qquad E^\circ = -0.36\ V$$

Very expensive – only used to prepare ultra-pure H_2

5) (*5 points*) A neutral macrocyclic ligand with four donor atoms produces a red diamagnetic low spin complex of Ni(II) with the two non coordinating nitrate anions (NO_3^-). When this nitrate anion is replaced by two thiocyanate anions, SCN^-, the complex turns violet and is high spin. Interpret the changes in terms of structure, magnetism, energy level and explain why?



Square planar d^8 Ni^{II} (diamagnetic) becomes octahedral complex upon coordination of NSC^- ligands. The octahedral ligand field leads to S=2 paramagnetic Ni^{II} (d^8) complex.

6) (*5 points*) Determine the oxidation state (ω) of the metals in the following compounds and give their *d* electron configuration (d^n)? Are they paramagnetic or diamagnetic? (*if the oxidation state or d^n configuration is wrong no partial marks will be given*)

a) $[Fe(en)_2Br_2]^+$

ω(Fe) = 3, d^5 > paramagnetic (Octahedral splitting)

b) $[Fe(SCN)_2Cl_2]^{2-}$

ω(Fe) = 2, d^6 > paramagnetic (tetrahedral or square planar complex)

c) $[IrCl_6]^{2-}$

ω(Ir) = 4, d^5> paramagnetic

d) Potassium chromate (K_2CrO_4)

2ω (K) + ω (Cr) + 4ω (O) = 0

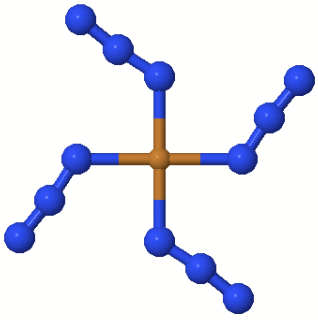
ω (Cr) = +6

Cr^{+6} d^0 > diamagnetic

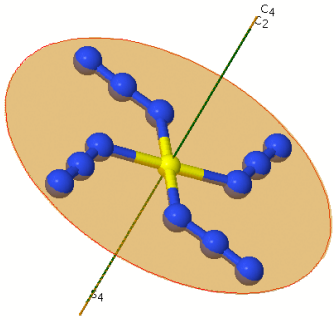
e) $[ScF_6]^{3-}$

ω (Sc) = +3, d^0 > diamagnetic

7) (10 points) The following molecule is called tetraazidocopper (II)



a) (7 points) Give **ALL** elements of symmetry for this molecule (draw them) and identify its point group.

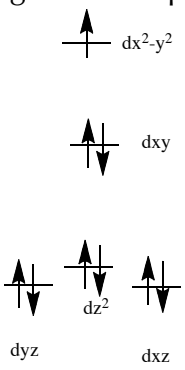


E, $1C_4$; $1C_2$, $1S_4$, $1\sigma_h$, i
Point group: C_{4h}

b) (1.5 points) Give the d^n electron configuration for the metal ion and determine if the molecule is paramagnetic? or diamagnetic?

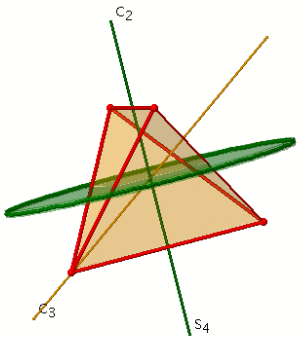
Cu(II) > $3d^9$ > paramagnetic

c) (1.5 points) Draw the energy level diagram with their labels based on ligand field splitting.



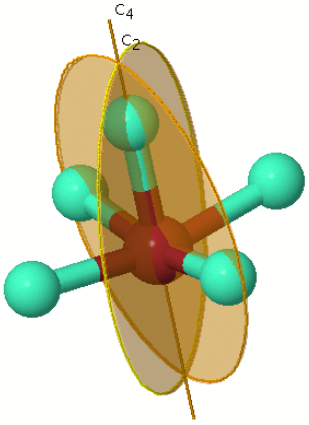
8) (10 points) Give all the symmetry elements for the following molecules and draw them cleanly. Identify the molecular point groups for the same compounds:

a) Tetrahedron
http://symmetry.otterbein.edu/gallery/index.html



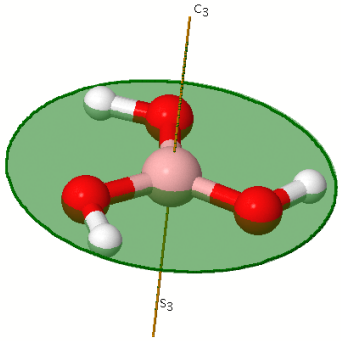
$4C_3$; $3C_2$; $3S_4$; $6\sigma_d$; point group=Td

b) BrF_5



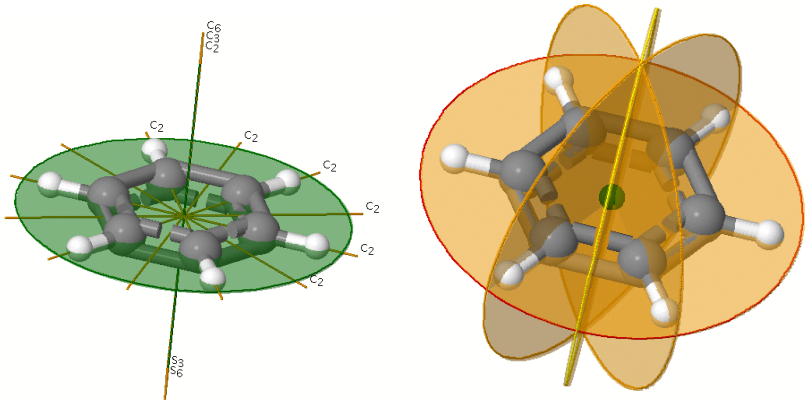
$1C_4$, C_2, $2\sigma_v$; $2\sigma_d$; point group=C_{4v}

c) Boric acid

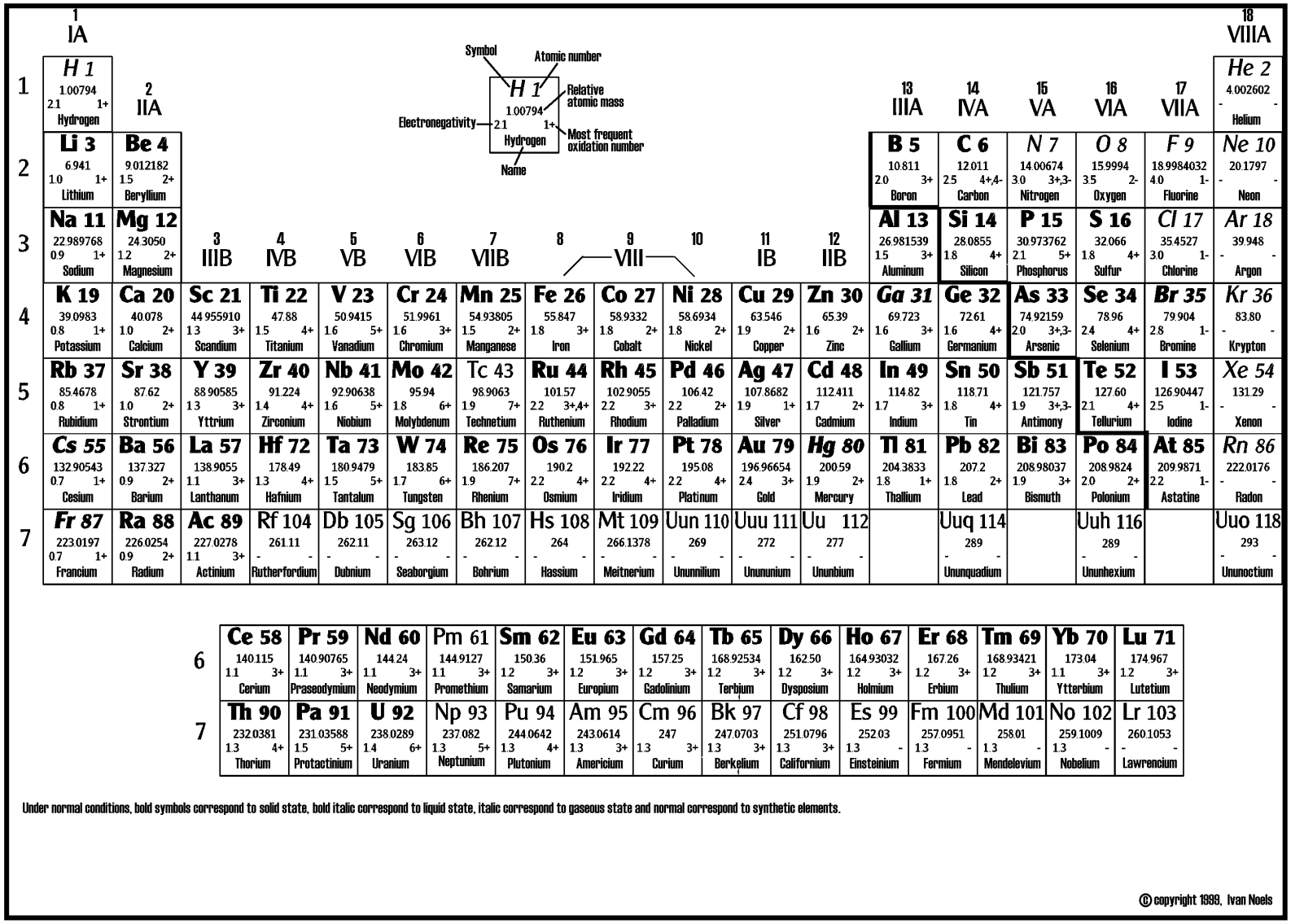


C_3, S_3, σ_h Point group: C_{3h}

d) Benzene



1 C_6, C_3, $7C_2$, S_6, S_3, i, 1 σ_h, $3\sigma_v$, $3\sigma_d$ Point group: D_{6h}


Symbol
Atomic number
H 1
1.00794
2.1 1+
Hydrogen
Relative atomic mass
Electronegativity
Most frequent oxidation number
Name
1 IA
2 IIA
3 IIIB
4 IVB
5 VB
6 VIB
7 VIIB
8
9 VIII
10
11 IB
12 IIB
13 IIIA
14 IVA
15 VA
16 VIA
17 VIIA
18 VIIIA
1 H 1 1.00794 2.1 1+ Hydrogen
2 He 4.002602 - - Helium
2 Li 6.941 1.0 1+ Lithium
Be 9.012182 1.5 2+ Beryllium
B 10.811 2.0 3+ Boron
C 12.011 2.5 4+,4- Carbon
N 14.00674 3.0 3+,3- Nitrogen
O 15.9994 3.5 2- Oxygen
F 18.9984032 4.0 1- Fluorine
Ne 20.1797 - - Neon
3 Na 22.989768 0.9 1+ Sodium
Mg 24.3050 1.2 2+ Magnesium
Al 26.981539 1.5 3+ Aluminum
Si 28.0855 1.8 4+ Silicon
P 30.973762 2.1 5+ Phosphorus
S 32.066 1.8 4+ Sulfur
Cl 35.4527 3.0 1- Chlorine
Ar 39.948 - - Argon
4 K 39.0983 0.8 1+ Potassium
Ca 40.078 1.0 2+ Calcium
Sc 44.955910 1.3 3+ Scandium
Ti 47.88 1.5 4+ Titanium
V 50.9415 1.6 5+ Vanadium
Cr 51.9961 1.6 3+ Chromium
Mn 54.93805 1.5 2+ Manganese
Fe 55.847 1.8 3+ Iron
Co 58.9332 1.8 2+ Cobalt
Ni 58.6934 1.8 2+ Nickel
Cu 63.546 1.9 2+ Copper
Zn 65.39 1.6 2+ Zinc
Ga 69.723 1.6 3+ Gallium
Ge 72.61 1.6 4+ Germanium
As 74.92159 2.0 3+,3- Arsenic
Se 78.96 2.4 4+ Selenium
Br 79.904 2.8 1- Bromine
Kr 83.80 - - Krypton
5 Rb 85.4678 0.8 1+ Rubidium
Sr 87.62 1.0 2+ Strontium
Y 88.90585 1.3 3+ Yttrium
Zr 91.224 1.4 4+ Zirconium
Nb 92.90638 1.6 5+ Niobium
Mo 95.94 1.8 6+ Molybdenum
Tc 43 98.9063 1.9 7+ Technetium
Ru 101.57 2.2 3+,4+ Ruthenium
Rh 102.9055 2.2 3+ Rhodium
Pd 106.42 2.2 2+ Palladium
Ag 107.8682 1.9 1+ Silver
Cd 112.411 1.7 2+ Cadmium
In 114.82 1.7 3+ Indium
Sn 118.71 1.8 4+ Tin
Sb 121.757 1.9 3+,3- Antimony
Te 127.60 2.1 4+ Tellurium
I 126.90447 2.5 1- Iodine
Xe 131.29 - - Xenon
6 Cs 55 132.90543 0.7 1+ Cesium
Ba 56 137.327 0.9 2+ Barium
La 57 138.9055 1.1 3+ Lanthanum
Hf 72 178.49 1.3 4+ Hafnium
Ta 73 180.9479 1.5 5+ Tantalum
W 74 183.85 1.7 6+ Tungsten
Re 75 186.207 1.9 7+ Rhenium
Os 76 190.2 2.2 4+ Osmium
Ir 77 192.22 2.2 4+ Iridium
Pt 78 195.08 2.2 4+ Platinum
Au 79 196.96654 2.4 3+ Gold
Hg 80 200.59 1.9 2+ Mercury
Tl 81 204.3833 1.8 1+ Thallium
Pb 82 207.2 1.8 2+ Lead
Bi 83 208.98037 1.9 3+ Bismuth
Po 84 208.9824 2.0 2+ Polonium
At 85 209.9871 2.2 1- Astatine
Rn 86 222.0176 - - Radon
7 Fr 87 223.0197 0.7 1+ Francium
Ra 88 226.0254 0.9 2+ Radium
Ac 89 227.0278 1.1 3+ Actinium
Rf 104 261.11 - - Rutherfordium
Db 105 262.11 - - Dubnium
Sg 106 263.12 - - Seaborgium
Bh 107 262.12 - - Bohrium
Hs 108 264 - - Hassium
Mt 109 266.1378 - - Meitnerium
Uun 110 269 - - Ununnilium
Uuu 111 272 - - Unununium
Uu 112 277 - - Ununbium
Uuq 114 289 - - Ununquadium
Uuh 116 289 - - Ununhexium
Uuo 118 293 - - Ununoctium
6 Ce 58 140.115 1.1 3+ Cerium
Pr 59 140.90765 1.1 3+ Praseodymium
Nd 60 144.24 1.1 3+ Neodymium
Pm 61 144.9127 1.1 3+ Promethium
Sm 62 150.36 1.2 3+ Samarium
Eu 63 151.965 1.2 3+ Europium
Gd 64 157.25 1.2 3+ Gadolinium
Tb 65 168.92534 1.2 3+ Terbium
Dy 66 162.50 1.2 3+ Dysposium
Ho 67 164.93032 1.2 3+ Holmium
Er 68 167.26 1.2 3+ Erbium
Tm 69 168.93421 1.2 3+ Thulium
Yb 70 173.04 1.1 3+ Ytterbium
Lu 71 174.967 1.2 3+ Lutetium
7 Th 90 232.0381 1.3 4+ Thorium
Pa 91 231.03588 1.5 5+ Protactinium
U 92 238.0289 1.4 6+ Uranium
Np 93 237.082 1.3 5+ Neptunium
Pu 94 244.0642 1.3 4+ Plutonium
Am 95 243.0614 1.3 3+ Americium
Cm 96 247 1.3 3+ Curium
Bk 97 247.0703 1.3 3+ Berkelium
Cf 98 251.0796 1.3 3+ Californium
Es 99 252.03 1.3 - Einsteinium
Fm 100 257.0951 1.3 - Fermium
Md 101 258.01 1.3 - Mendelevium
No 102 259.1009 1.3 - Nobelium
Lr 103 260.1053 - - Lawrencium
Under normal conditions, bold symbols correspond to solid state, bold italic correspond to liquid state, italic correspond to gaseous state and normal correspond to synthetic elements.
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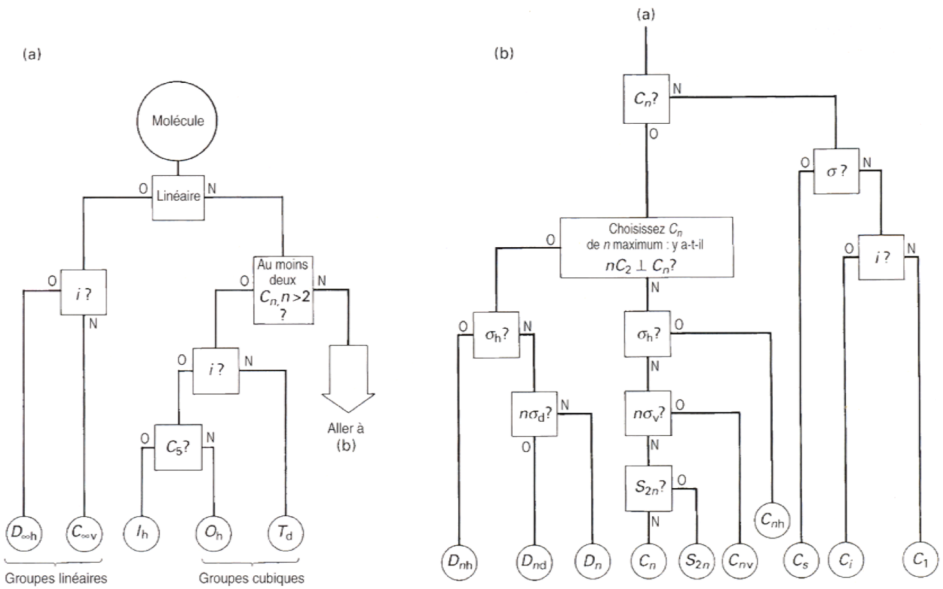

4.9 Schéma de décision pour l'identification d'un groupe ponctuel moléculaire. Après avoir traversé la partie (a), passez à la partie (b) si nécessaire. Les symboles à chaque point de décision se rapportent aux éléments de symétrie (et non aux opérations correspondantes).