**CHEM 208 – Coordination Chemistry**

Physical and Chemical Properties of Coordination Compounds

# Midterm Exam #1

## October 7th, 2016

| | |
|---|---|
| *Family/Last Name:* _____ | *First Name:* _____ |
| *CHEM 208 Team:* _____ | *SUID:* _____ |
| *Signature:* _____ | |

***INSTRUCTIONS***

1. You have 50 minutes for this exam.
2. Check that this exam booklet consists of **5 PAGES PRINTED ON BOTH SIDES**. There is one blank page in case you need extra space to work on problems.
3. The datasheet and periodic table (last page of this booklet) may be removed.
4. Write all answers on the answer sheet provided. Answer written in this question booklet will not be marked.
5. The only calculator allowed is the Sharp EL-510R. All other calculators/electronic devices will be confiscated.
6. Molecular model kits may be used and may be pre-assembled.

***RULES GOVERNING FORMAL EXAMINATIONS***

1. Each examination candidate must be prepared to produce, upon the request of the invigilator or examiner, their UBCcard for identification.
2. Examination candidates are not permitted to ask questions of the examiners or invigilators, except in cases of supposed errors or ambiguities in examination questions, illegible or missing material, or the like.
3. No examination candidate shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during the first half hour of the examination. Should the examination run forty-five (45) minutes or less, no examination candidate shall be permitted to enter the examination room once the examination has begun.
4. Examination candidates must conduct themselves honestly and in accordance with established rules for a given examination, which will be articulated by the examiner or invigilator prior to the examination commencing. Should dishonest behaviour be observed by the examiner(s) or invigilator(s), pleas of accident or forgetfulness shall not be received.
5. Examination candidates suspected of any of the following, or any other similar practices, may be immediately dismissed from the examination by the examiner/invigilator, and may be subject to disciplinary action:
   - speaking or communicating with other examination candidates, unless otherwise authorized;
   - purposely exposing written papers to the view of other examination candidates or imaging devices;
   - purposely viewing the written papers of other examination candidates;
   - using or having visible at the place of writing any books, papers or other memory aid devices other than those authorized by the examiner(s); and,
   - using or operating electronic devices including but not limited to telephones, calculators, computers, or similar devices other than those authorized by the examiner(s)—(electronic devices other than those authorized by the examiner(s) must be completely powered down if present at the place of writing).
6. Examination candidates must not destroy or damage any examination material, must hand in all examination papers, and must not take any examination material from the examination room without permission of the examiner or invigilator.
7. Examination candidates must follow any additional examination rules or directions communicated by the examiner(s) or invigilator(s).

***Part 1.*** ***(16 marks total, 2 mark each)***

For each question below, enter the best answer on the separate answer sheet provided. **Answers recorded here will NOT be graded.**

1. What is the correct valence electronic configuration for a $Cu^{2+}$ ion?

   a) $[Ar]4s^2 3d^7$
   b) $[Ar]4s^1 3d^8$
   c) $[Ar]4s^0 3d^9$
   d) $[Ar]4s^2 3d^9$
   e) $[Ar]4s^1 3d^{10}$
   f) none of the above

2. What is the best way to describe the Pt-Cl bonds in cisplatin?

   a) coordinate bonds where both electrons are owned by a formally anionic chlorido ligand
   b) coordinate bonds where both electrons are owned by a formally neutral chlorido ligand
   c) coordinate bonds where both electrons are owned by the cationic metal centre
   d) polar covalent bonds where the electrons are shared between the two partners
   e) polar covalent bonds where the electrons are mostly on the metal centre
   f) none of the above

3. What is the correct way to describe $Co(en)_2Cl_2$ using the covalent bond classification method?

   a) $ML_4X_2$
   b) $ML_2X_2$
   c) $ML_6$
   d) $ML_4$
   e) $MX_4$
   f) $MX_6$

   each en ligand is worth L2

4. For which of the following is it ***not possible*** for the metal to be iron(III)?

   a) $[ML_4X_2]^+$
   b) $ML_3X_3$
   c) $[ML_5X]^{2+}$
   d) $[MX_6]^{3-}$
   e) $[ML_6]^{3+}$
   f) none of the above

5. The empirical formula for a complex is $Fe(NH_3)_6Cl_3$. The conductivity of a 1M solution of this complex in water is no different than that of water itself. Lastly, you know that the molecule has a three-fold axis of symmetry. Which species is it?

   a) *mer*-$Fe(NH_3)_3Cl_3 \bullet 3NH_3$
   b) *fac*-$Fe(NH_3)_3Cl_3 \bullet 3NH_3$
   c) *cis*-$[Fe(NH_3)_4Cl_2]Cl \bullet 2NH_3$
   d) *trans*-$[Fe(NH_3)_4Cl_2]Cl \bullet 2NH_3$
   e) $[Fe(NH_3)_6]Cl_3$
   f) none of the above

6. An *inner sphere* ligand is

   a) a proligand that helps create a sphere around a metal ion
   b) a chemical species that binds directly to a metal centre through a coordinate bond
   c) a chemical entity that is a counterion to a charged metal complex
   d) a neutral molecule that binds directly a metal centre
   e) an anion that is attracted to a metal ion through electrostatic interactions
   f) none of the above

7. Which of the following is **true** about the Lewis adduct formed between water and boron trifluoride?

   a) a coordinate bond is formed from B to O and formal charges are created
   b) a coordinate bond is formed from O to B and formal charges are created
   c) a coordinate bond is formed from a F to the O and formal charges are created
   d) a coordinate bond is formed from B to O and formal charges on these atoms do not change
   e) a coordinate bond is formed from O to B and formal charges on these atoms do not change
   f) a coordinate bond is formed from a F to the O and formal charges on these atoms do not change

8. Which of the following complexes includes a metal with a $d^5$ electronic configuration?

   a) $Co(en)_2Cl_2$
   b) $Fe(phen)_2Cl_2$
   c) $Mn(NH_3)_3Cl_3$
   d) $[Mn(NR_3)_4Cl_2]^{1+}$
   e) none of the above
   f) all of the above

***Part 2.*** ***(34 marks total)***

In this part of the exam, your answers will also be in the form of a multiple choice response. However, a series of questions will all share the same series of possible answers. These are listed at the beginning of the question.

**Q9-14. (2 marks each)** The reaction of carbon monoxide with $OsCl_3$ yields numerous products. Each of the products is an *six-coordinate* Os(III) complex with varying combinations of CO and Cl ligands. Identify the appropriate complex corresponding to each of the statements. **Important:** In some cases, more than one answer may be a reasonable, however, *you cannot use an answer more than once!* We strongly suggest that you determine your final set of answers *before* filling in the bubble sheet.

a) hexacarbonylosmium(III) chloride
b) $[Os(CO)_5Cl]Cl_2$
c) *cis*-dicarbonyltetrachloridoosmium(III) chloride
d) *trans*-$[Os(CO)_4Cl_2]Cl$
e) *mer*-$Os(CO)_3Cl_3$
f) *fac*-tricarbonyltrichloroosmium(III)
g) none of the above

9. This species, when dissolved in water, will *not* show a precipitate upon addition of $AgNO_3$. E (F already used)

10. The metal complex in this species has axial symmetry. F (B, D also reasonable but already used)

11. This species would result in the largest conductivity when dissolved in water. A is the only valid answer

12. The metal complex in this species is of the same point group as $BrF_5$. B is the only valid answer

13. The metal complex in this species is part of a dihedral point group. D or G

14. The freezing point of a **1 mol/l** aqueous solution of this complex would be the same as that of a **2 mol/l** aqueous solution of ammonia.

D or G, C is NOT a valid compound but was accepted.

**Q15-20. (2 marks each)** Answer the following questions using the possible answers given below. Each question has a single correct answer. *Answers can be used more than once.*

a) $C_3$
b) $C_{3v}$
c) $C_{3h}$
d) $D_3$
e) $D_{3d}$
f) $D_{3h}$
g) $C_4$
h) $C_{4v}$
i) $C_{4h}$
j) $D_4$
k) $D_{4d}$
l) $D_{4h}$
m) $T_d$
n) $O_h$
o) $I_h$
p) $C_2$
q) $C_{2v}$
r) none of the above

15. $[CoCl_4]^{2-}$ is an *isotropic* dianion. What is the correct symmetry of this species?

M

16. What is the correct symmetry for the diastereomer of $[PtCl_4Br_2]^{2-}$ that belongs to a *dihedral* point group?

L

17. What is the correct symmetry for the diastereomer of $[PtCl_4Br_2]^{2-}$ that belongs to a *cyclic* point group?

Q

18. What is the correct symmetry for Δ-$Ru(phen)_2Br_2$? (*hint:* Recall that the phen ligand is a planar ligand with two nitrogen atoms that serve as ligands)

P

19. What is the correct symmetry for the achiral form of $Ru(phen)_2Br_2$?

R (D2h)

20. What is the correct symmetry for the *cis*-dichloridodibromidopalladium(II) dianion?

Q

**Q21-25. (2 marks each)** Answer the following questions using the possible answers given below. Each question has a single correct answer. *Answers can be used more than once.*

a) E
b) $C_2$
c) $C_3$
d) $C_4$
e) $C_5$
f) $C_6$
g) $S_1$
h) $S_3$
i) $S_4$
j) $S_5$
k) $S_6$
l) $\sigma_v$
m) $\sigma_h$
n) i
o) none of the above

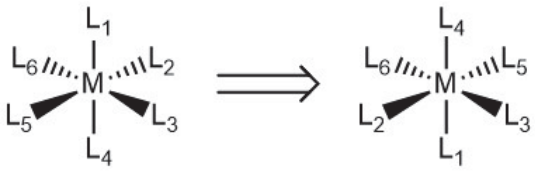
21. Which symmetry element correlates with the point of the $C_{3v}$ point group?

C

22. If you have a $C_3$ axis and no reflection planes in a molecule, what type of improper axis of rotation might exist in this molecule?

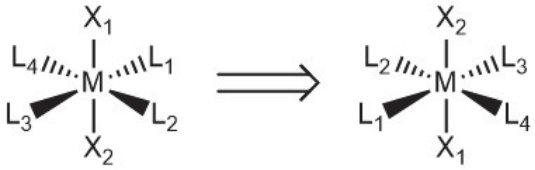
K (look at the flowchart...)

23. Which symmetry element would be responsible for the following transformation? (note that there is only one type of ligand in this complex)




B

24. Which symmetry element would be responsible for the following transformation? (note that there are two different types of ligands in this complex)




N

25. Which symmetry element is equivalent to performing an $S_3$ three times ($S_3^3$) when the $S_3$ axis is the primary axis in this system?

M

***END OF EXAM***

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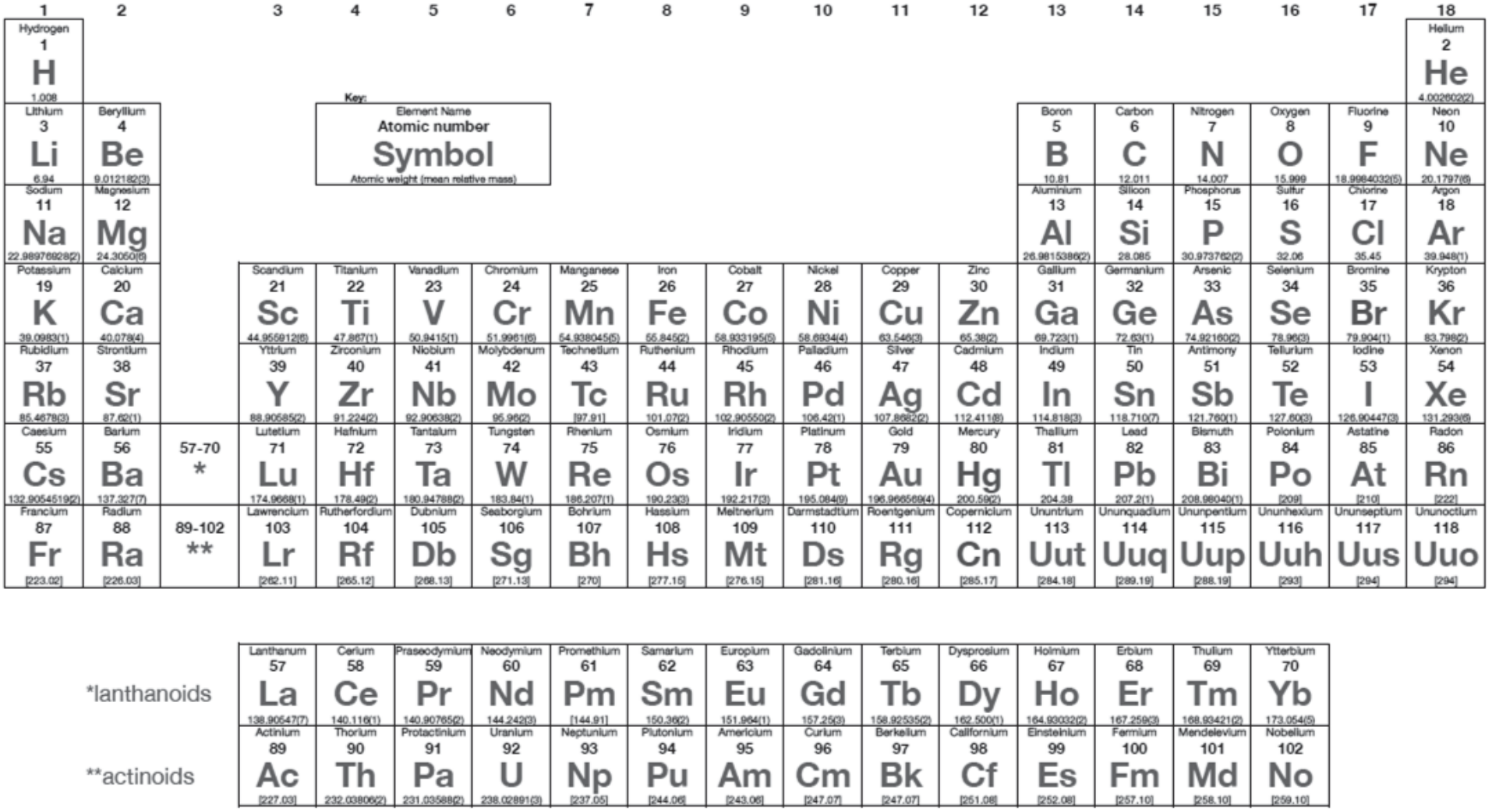
1
2
3
4
5
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7
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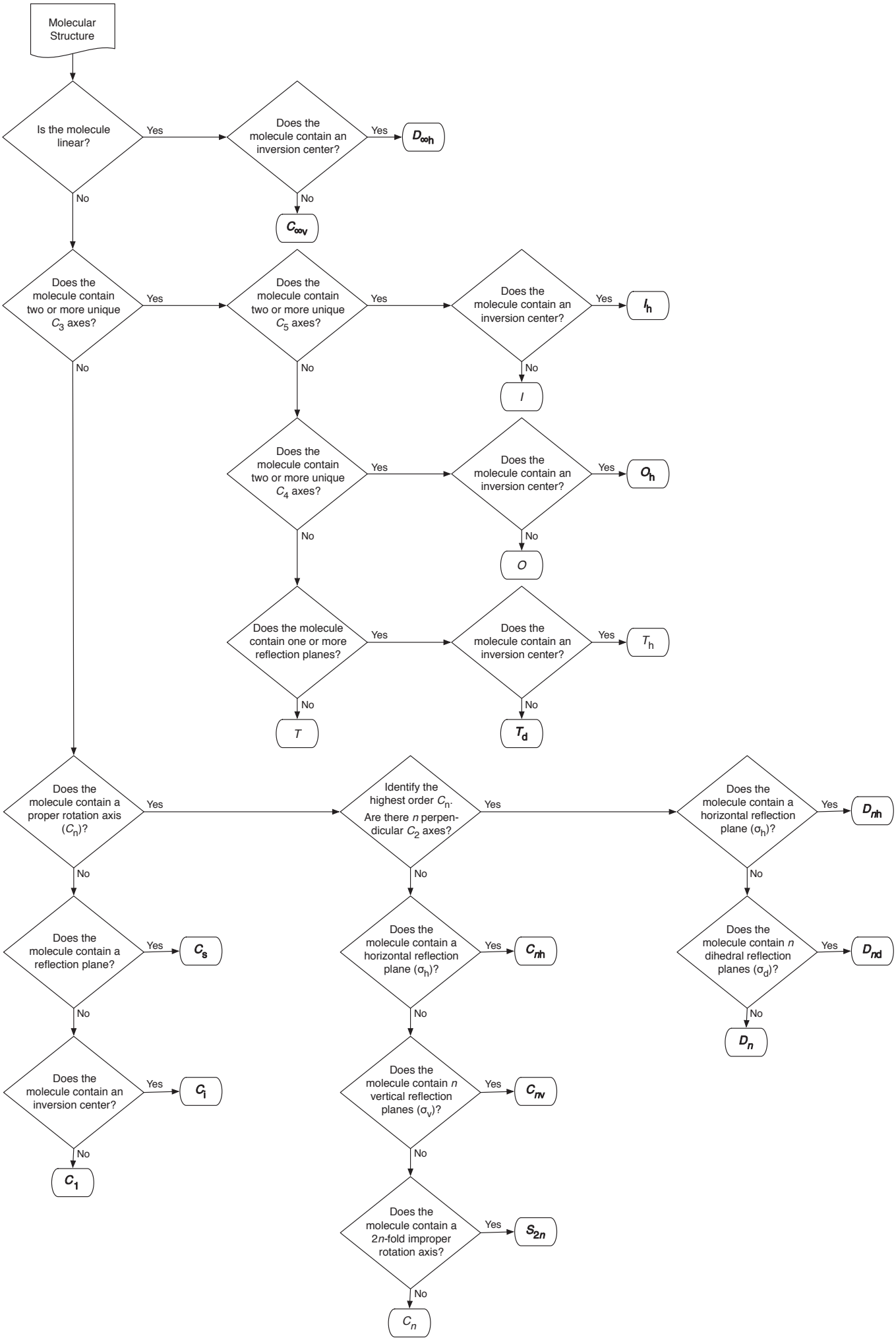
9
10
11
12
13
14
15
16
17
18
Hydrogen 1 H 1.008
Helium 2 He 4.002602(2)
Key:
Element Name
Atomic number
Symbol
Atomic weight (mean relative mass)
Lithium 3 Li 6.94
Beryllium 4 Be 9.012182(3)
Boron 5 B 10.81
Carbon 6 C 12.011
Nitrogen 7 N 14.007
Oxygen 8 O 15.999
Fluorine 9 F 18.9984032(5)
Neon 10 Ne 20.1797(6)
Sodium 11 Na 22.98976928(2)
Magnesium 12 Mg 24.3050(6)
Aluminium 13 Al 26.9815386(2)
Silicon 14 Si 28.085
Phosphorus 15 P 30.973762(2)
Sulfur 16 S 32.06
Chlorine 17 Cl 35.45
Argon 18 Ar 39.948(1)
Potassium 19 K 39.0983(1)
Calcium 20 Ca 40.078(4)
Scandium 21 Sc 44.955912(6)
Titanium 22 Ti 47.867(1)
Vanadium 23 V 50.9415(1)
Chromium 24 Cr 51.9961(6)
Manganese 25 Mn 54.938045(5)
Iron 26 Fe 55.845(2)
Cobalt 27 Co 58.933195(5)
Nickel 28 Ni 58.6934(4)
Copper 29 Cu 63.546(3)
Zinc 30 Zn 65.38(2)
Gallium 31 Ga 69.723(1)
Germanium 32 Ge 72.63(1)
Arsenic 33 As 74.92160(2)
Selenium 34 Se 78.96(3)
Bromine 35 Br 79.904(1)
Krypton 36 Kr 83.798(2)
Rubidium 37 Rb 85.4678(3)
Strontium 38 Sr 87.62(1)
Yttrium 39 Y 88.90585(2)
Zirconium 40 Zr 91.224(2)
Niobium 41 Nb 92.90638(2)
Molybdenum 42 Mo 95.96(2)
Technetium 43 Tc [97.91]
Ruthenium 44 Ru 101.07(2)
Rhodium 45 Rh 102.90550(2)
Palladium 46 Pd 106.42(1)
Silver 47 Ag 107.8682(2)
Cadmium 48 Cd 112.411(8)
Indium 49 In 114.818(3)
Tin 50 Sn 118.710(7)
Antimony 51 Sb 121.760(1)
Tellurium 52 Te 127.60(3)
Iodine 53 I 126.90447(3)
Xenon 54 Xe 131.293(6)
Caesium 55 Cs 132.90545192(2)
Barium 56 Ba 137.327(7)
57-70 *
Lutetium 71 Lu 174.9668(1)
Hafnium 72 Hf 178.49(2)
Tantalum 73 Ta 180.94788(2)
Tungsten 74 W 183.84(1)
Rhenium 75 Re 186.207(1)
Osmium 76 Os 190.23(3)
Iridium 77 Ir 192.217(3)
Platinum 78 Pt 195.084(9)
Gold 79 Au 196.966569(4)
Mercury 80 Hg 200.59(2)
Thallium 81 Tl 204.38
Lead 82 Pb 207.2(1)
Bismuth 83 Bi 208.98040(1)
Polonium 84 Po [209]
Astatine 85 At [210]
Radon 86 Rn [222]
Francium 87 Fr [223.02]
Radium 88 Ra [226.03]
89-102 **
Lawrencium 103 Lr [262.11]
Rutherfordium 104 Rf [265.12]
Dubnium 105 Db [268.13]
Seaborgium 106 Sg [271.13]
Bohrium 107 Bh [270]
Hassium 108 Hs [277.15]
Meitnerium 109 Mt [276.15]
Darmstadtium 110 Ds [281.16]
Roentgenium 111 Rg [280.16]
Copernicium 112 Cn [285.17]
Ununtrium 113 Uut [284.18]
Ununquadium 114 Uuq [289.19]
Ununpentium 115 Uup [288.19]
Ununhexium 116 Uuh [293]
Ununseptium 117 Uus [294]
Ununoctium 118 Uuo [294]
*lanthanoids
Lanthanum 57 La 138.90547(7)
Cerium 58 Ce 140.116(1)
Praseodymium 59 Pr 140.90765(2)
Neodymium 60 Nd 144.242(3)
Promethium 61 Pm [144.91]
Samarium 62 Sm 150.36(2)
Europium 63 Eu 151.964(1)
Gadolinium 64 Gd 157.25(3)
Terbium 65 Tb 158.92535(2)
Dysprosium 66 Dy 162.500(1)
Holmium 67 Ho 164.93032(2)
Erbium 68 Er 167.259(3)
Thulium 69 Tm 168.93421(2)
Ytterbium 70 Yb 173.054(5)
**actinoids
Actinium 89 Ac [227.03]
Thorium 90 Th 232.03806(2)
Protactinium 91 Pa 231.03588(2)
Uranium 92 U 238.02891(3)
Neptunium 93 Np [237.05]
Plutonium 94 Pu [244.06]
Americium 95 Am [243.06]
Curium 96 Cm [247.07]
Berkelium 97 Bk [247.07]
Californium 98 Cf [251.08]
Einsteinium 99 Es [252.08]
Fermium 100 Fm [257.10]
Mendelevium 101 Md [258.10]
Nobelium 102 No [259.10]


Molecular Structure
Is the molecule linear?
Yes
Does the molecule contain an inversion center?
Yes
$D_{\infty h}$
No
$C_{\infty v}$
No
Does the molecule contain two or more unique $C_3$ axes?
Yes
Does the molecule contain two or more unique $C_5$ axes?
Yes
Does the molecule contain an inversion center?
Yes
$I_h$
No
$I$
No
Does the molecule contain two or more unique $C_4$ axes?
Yes
Does the molecule contain an inversion center?
Yes
$O_h$
No
$O$
No
Does the molecule contain one or more reflection planes?
Yes
Does the molecule contain an inversion center?
Yes
$T_h$
No
$T$
No
$T_d$
No
Does the molecule contain a proper rotation axis ($C_n$)?
Yes
Identify the highest order $C_n$. Are there $n$ perpendicular $C_2$ axes?
Yes
Does the molecule contain a horizontal reflection plane ($\sigma_h$)?
Yes
$D_{nh}$
No
Does the molecule contain a reflection plane?
Yes
$C_s$
No
Does the molecule contain a horizontal reflection plane ($\sigma_h$)?
Yes
$C_{nh}$
No
Does the molecule contain $n$ dihedral reflection planes ($\sigma_d$)?
Yes
$D_{nd}$
No
$D_n$
No
Does the molecule contain an inversion center?
Yes
$C_i$
No
$C_1$
No
Does the molecule contain $n$ vertical reflection planes ($\sigma_v$)?
Yes
$C_{nv}$
No
Does the molecule contain a $2n$-fold improper rotation axis?
Yes
$S_{2n}$
No
$C_n$