

**Chemistry 121**  
**The University of British Columbia**  
**Midterm Examination 1**  
**October 6, 2016**

Put the first letter of your family/last name in this box.

Time: **60 minutes**

Family/Last Name: \_\_\_\_\_  
 (printed)

First Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Student Number: \_\_\_\_\_

Please check  $\checkmark$  your lecture section:

<input type="checkbox"/> 101 (MWF 1:00 PM)	Krems
<input type="checkbox"/> 102 (MWF 2:00 PM)	Orvig
<input type="checkbox"/> 103 (MWF 3:00 PM)	Orvig
<input type="checkbox"/> 110 (MWF 10:00 AM)	Lindenberg
<input type="checkbox"/> 111 (MWF 11:00 AM)	McIntosh
<input type="checkbox"/> 122 (T,Th 2:00 PM)	Hudson
<input type="checkbox"/> 133 (T,Th 3:30 PM)	Terpstra
<input type="checkbox"/> 188 (T,Th 8:00 AM)	Legzdins
<input type="checkbox"/> 199 (T,Th 9:30 AM)	Therrien
<input type="checkbox"/> V02 (MWF 1:00 PM)	Lekhi

### INSTRUCTIONS

Check that this examination consists of **12 pages total, printed on both sides**. The last sheet (pages 11 and 12), containing Supplementary Information and the Periodic Table, may be detached for ease of use.

**Using dark ink, fill in your name, student number, section, and the 1<sup>st</sup> letter of your last name on this exam booklet and on your bubble sheet. Sign both.**

Use your **bubble sheet to answer questions 1 - 17**. Completely fill in the circle that corresponds to your best answer using **dark pencil or ink**. Only the bubble sheet will be marked. You will receive zero for each unanswered question.

To change your answer after filling in a bubble:

- if you used pencil, then erase the pencil marks completely from the answer(s) that you do not want marked.
- if you used pen, then put a clear "X" over the answer(s) you do not want marked.

For the remaining **questions 18 - 20**, please write all of your answers directly on this examination booklet.

At the end of the exam, **insert** your bubble sheet into this booklet and hand both to an invigilator.

The only calculators allowed are the **Sharp EL-510** series. All other calculators will be confiscated. Cell phones or other electronic communication devices are not permitted on the examination desks and must be powered off. Unassembled molecular model kits may be used.

## **RULES GOVERNING FORMAL EXAMINATIONS**

Each examination candidate must be prepared to produce, upon the request of the invigilator or examiner, his or her UBCcard for identification.

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.

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.

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.

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:

- i. speaking or communicating with other examination candidates, unless otherwise authorized;
- ii. purposely exposing written papers to the view of other examination candidates or imaging devices;
- iii. purposely viewing the written papers of other examination candidates;
- iv. 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,
- v. 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).

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.

Notwithstanding the above, for any mode of examination that does not fall into the traditional, paper-based method, examination candidates shall adhere to any special rules for conduct as established and articulated by the examiner.

Examination candidates must follow any additional examination rules or directions communicated by the examiner(s) or invigilator(s).

**PART I. Multiple Choice (30 marks total)**

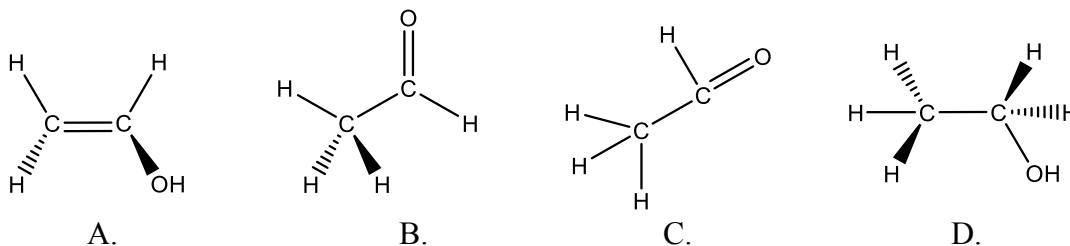
For each numbered statement below, record the letter for the best answer on your bubble sheet. There is only one correct answer per question. Each of the 15 questions is worth **2 marks**.

- Which of the following species contains only ionic bonds?
  - $\text{NaN}_3$
  - $\text{CaF}_2$
  - $\text{H}_2\text{SO}_4$
  - $\text{NH}_4\text{Cl}$
  - $\text{Li}_3\text{PO}_4$
- Which of the following ionic compounds is predicted to have the greatest lattice energy?
  - $\text{NaCl}$
  - $\text{NaBr}$
  - $\text{BaS}$
  - $\text{KCl}$
  - $\text{MgS}$
- Which of the following molecules cannot be represented by a Lewis structure with a complete octet on each atom?
  - $\text{O}_2$
  - $\text{CO}$
  - $\text{N}_2$
  - $\text{NO}_2$
  - $\text{N}_2\text{O}$
- How many single bonds are present in the best Lewis structure of perchloric acid,  $\text{HClO}_4$ ?
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
- What are the F—I—F bond angles in  $[\text{IF}_4]^-$ ?
  - All angles are  $109.5^\circ$
  - All angles are  $120^\circ$
  - $120^\circ, 90^\circ$
  - $180^\circ, 90^\circ$
  - $180^\circ, 120^\circ, 90^\circ$

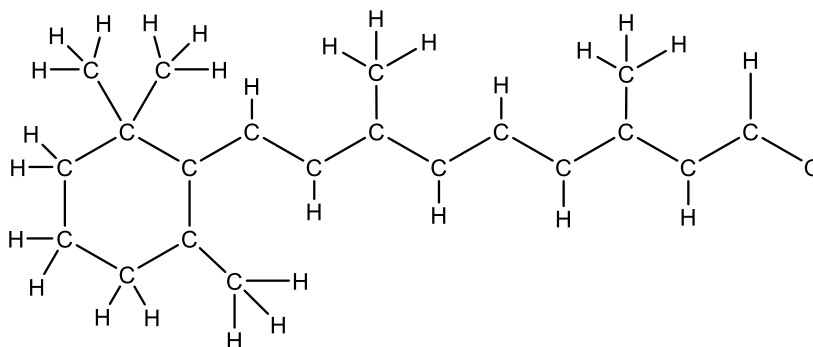
6. Which of the following molecules possesses a permanent dipole moment?

- A.  $\text{XeF}_2$
- B.  $\text{XeF}_4$
- C.  $\text{SF}_4$
- D.  $\text{PF}_5$
- E.  $\text{SiF}_4$

7. Which of the following is a correctly drawn perspective diagram for  $\text{C}_2\text{H}_4\text{O}$ ?



8. The molecule retinal ( $\text{C}_{20}\text{H}_{28}\text{O}$ ) is a form of vitamin A that we require for vision. The skeletal structure of retinal is shown below. Multiple bonds and lone electron pairs are not indicated.



How many double bonds are present in the best Lewis structure of retinal?

- A. 0
- B. 2
- C. 4
- D. 6
- E. 8
- F. 10

9. Molecules with this shape are always polar:

- A. octahedral
- B. trigonal planar
- C. T-shaped
- D. linear
- E. tetrahedral

10. Which one of the following molecules or ions cannot react as a Lewis base?
- A.  $\text{CH}_4$
  - B.  $\text{CN}^-$
  - C.  $\text{CH}_3\text{NH}_2$
  - D.  $\text{Cl}^-$
  - E.  $\text{H}_2\text{O}$
11. What are the wavelength ( $\lambda$ ) and amplitude ( $A$ ) of the wave formed by the interference of 10 identical waves, each with wavelength 1 cm and amplitude 1? The crests of all 10 waves are aligned.
- A.  $\lambda = 1 \text{ cm}; \quad A = 1$
  - B.  $\lambda = 10 \text{ cm}; \quad A = 1$
  - C.  $\lambda = 1 \text{ cm}; \quad A = 5$
  - D.  $\lambda = 1 \text{ cm}; \quad A = 10$
  - E.  $\lambda = 10 \text{ cm}; \quad A = 10$
12. Microwaves are a form of electromagnetic radiation (light). What is the wavelength of the microwaves ( $\nu = 2400 \text{ MHz}$ ) used to cook food in a household microwave oven?
- A.  $8 \mu\text{m}$
  - B.  $1250 \mu\text{m}$
  - C.  $12.5 \text{ cm}$
  - D.  $800 \text{ cm}$
  - E.  $1.25 \times 10^5 \text{ m}$
13. How many nodes does a standing wave with a wavelength of 5 cm have in a box of length 10 cm?
- A. 0
  - B. 1
  - C. 2
  - D. 3
  - E. 4
  - F. 5
14. A particle with velocity  $2.5 \times 10^4 \text{ m s}^{-1}$  has a de Broglie wavelength of 0.5 pm. That particle could be a/an:
- A. photon
  - B. electron
  - C. neutron
  - D.  $\text{O}_2$  molecule
  - E. Ar atom

15. Which of the following statements is incorrect?

- A. The wavelength of an electron is always larger than the wavelength of a proton.
- B. Both protons and electrons can exhibit a diffraction pattern.
- C. Electrons in an atom must be treated as waves because their wavelengths are comparable with the size of the atom.
- D. A macroscopic object such as a tennis ball does not exhibit diffraction because its wavelength is much smaller than its size.
- E. A diffraction pattern formed by electrons passed through a lattice of gold atoms is a result of destructive and constructive interference of scattered waves.

**PART II. Short Answer Questions (30 marks total)**

**(5 marks)**

16. Complete the following statements about  $\text{N}_2\text{H}_2$  (diazene) and  $\text{N}_2\text{H}_4$  (hydrazine). Record your answers to parts (a)-(e) on your bubble sheet.

(a) The bond order of the nitrogen-nitrogen bond in  $\text{N}_2\text{H}_2$  is:

- A. 1
- B. between 1 and 2
- C. 2
- D. between 2 and 3
- E. 3

(b) The bond order of each nitrogen-hydrogen bond in  $\text{N}_2\text{H}_2$  is:

- A. 1
- B. between 1 and 2
- C. 2
- D. between 2 and 3
- E. 3

(c) The maximum number of co-planar atoms that can occur in the molecular structure of  $\text{N}_2\text{H}_4$  is:

- A. 3
- B. 4
- C. 5
- D. 6

(d) Which has the shorter nitrogen-nitrogen bond length?

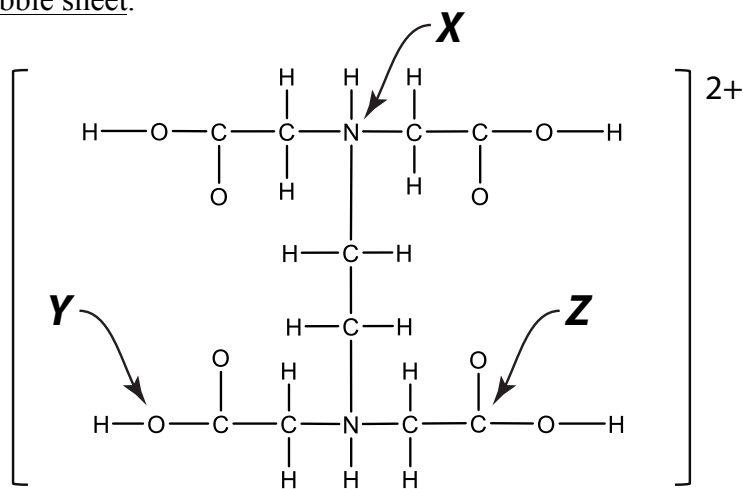
- A.  $\text{N}_2\text{H}_2$  (diazene)
- B.  $\text{N}_2\text{H}_4$  (hydrazine)

(e) Which has the smaller nitrogen-nitrogen bond dissociation energy?

- A.  $\text{N}_2\text{H}_2$  (diazene)
- B.  $\text{N}_2\text{H}_4$  (hydrazine)

**(6 marks)**

17. Shown is the skeletal structure of  $\text{EDTA}^{2+}$ , a food additive that traps metal impurities. Multiple bonds, lone electron pairs, and formal charges are not indicated. Record your answers to parts (a)-(f) on your bubble sheet.

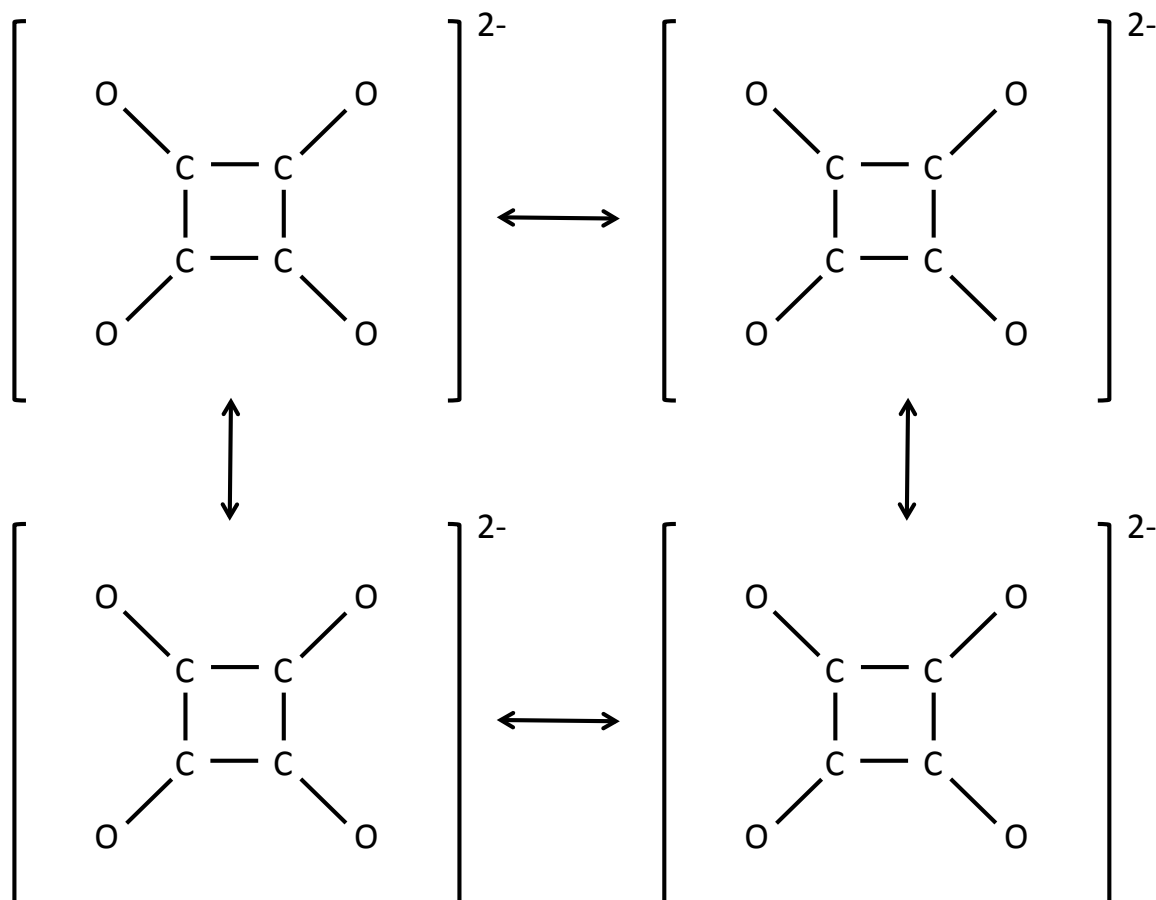


<p>(a) The molecular shape at the atom labeled <b>X</b> is:</p> <p>A. bent            B. see-saw            C. tetrahedral            D. trigonal planar            E. trigonal pyramidal</p>	<p>(d) The number of carbon atoms with tetrahedral molecular shape in <math>\text{EDTA}^{2+}</math> is:</p> <p>A. 0            B. 2            C. 4            D. 6            E. 10</p>
<p>(b) The estimated H–O–C bond angle at the atom labeled <b>Y</b> is:</p> <p>A. <math>72^\circ</math>            B. <math>90^\circ</math>            C. <math>109.5^\circ</math>            D. <math>120^\circ</math>            E. <math>180^\circ</math></p>	<p>(e) The formal charge on the atom labeled <b>X</b> in the best Lewis structure is:</p> <p>A. <math>-2</math>            B. <math>-1</math>            C. <math>0</math>            D. <math>+1</math>            E. <math>+2</math></p>
<p>(c) The estimated O–C–O bond angle at the atom labeled <b>Z</b> is:</p> <p>A. <math>72^\circ</math>            B. <math>90^\circ</math>            C. <math>109.5^\circ</math>            D. <math>120^\circ</math>            E. <math>180^\circ</math></p>	<p>(f) The partial charge of the atom labeled <b>Y</b> is:</p> <p>A. <math>\delta+</math>            B. <math>0</math>            C. <math>\delta-</math>            D. none of the above</p>

For the remaining questions, write your answers within this exam booklet.

(4 marks)

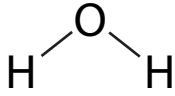
18. Draw the 4 best resonance Lewis structures for the squarate anion,  $[\text{C}_4\text{O}_4]^{2-}$  by neatly completing the skeletal structures below. Show all lone pairs of electrons as pairs of dots and all additional bonds as lines. Write any non-zero formal charges on the appropriate atoms.



You may use the space below for rough work, but only the above 4 diagrams will be marked.

(9 marks)

19. Complete the following table by drawing the best Lewis structure for each of the specified molecules (central atom underlined), showing all lone pairs of electrons as pairs of dots and all bonds as lines. Write any non-zero formal charges on the appropriate atoms. Use VSEPR rules and the information on polarity given in the table below to name the molecular shape and draw a perspective diagram for each of these molecules. The first row is completed as an example.

	Lewis Structure	Perspective Diagram	Polar or Non-polar
<b>H<sub>2</sub>O</b>	$\text{H} - \underset{\cdot\cdot}{\underset{\cdot\cdot}{\text{O}}} - \text{H}$	 Molecular shape: <u>bent</u>	<b>polar</b>
<b><u>P</u>OCl<sub>3</sub></b>		Mol. shape: _____	<b>polar</b>
<b><u>P</u>Cl<sub>3</sub>F<sub>2</sub></b>		Mol. shape: _____	<b>non-polar</b>
<b>[<u>I</u>Br<sub>2</sub>F<sub>2</sub>]<sup>-</sup></b>		Mol. shape: _____	<b>polar</b>

(6 marks)

20. Match the following six triatomic molecules to the six statements below.

**USE EACH MOLECULE ONLY ONCE**

Some molecules will fit for multiple statements, but there is only one solution where each molecule is used only once. The triatomic molecules (central atom is underlined) are:



(a) Is a radical:

\_\_\_\_\_

(b) Has two equivalent resonance structures:

\_\_\_\_\_

(c) Has a linear molecular shape:

\_\_\_\_\_

(d) Has a bent molecular shape:

\_\_\_\_\_

(e) Has an expanded octet:

\_\_\_\_\_

(f) Does not have a permanent net dipole moment:

\_\_\_\_\_

**END OF EXAMINATION**

## Supplementary Sheet

(you may detach and recycle after completing the exam)

### *Potentially useful constants and conversion factors*

$$1 \text{ Hertz} = 1 \text{ Hz} = 1 \text{ s}^{-1} = 10^{-6} \text{ MHz}$$

$$1 \text{ m} = 10^6 \mu\text{m} = 10^9 \text{ nm} = 10^{10} \text{ \AA} = 10^{12} \text{ pm}$$

$$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$h = \text{Planck's constant} = 6.626 \times 10^{-34} \text{ J s}$$

$$N_A = \text{Avogadro's number} = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$c = \text{speed of light} = 3.00 \times 10^8 \text{ m s}^{-1}$$

$$1 \text{ amu} = 1 \text{ u} = \text{atomic mass unit} = 1.66 \times 10^{-27} \text{ kg}$$

$$\text{electron mass} = 9.11 \times 10^{-31} \text{ kg}$$

$$\text{proton mass} = 1.67 \times 10^{-27} \text{ kg}$$

$$a_o = \text{Bohr radius} = 0.53 \text{ \AA}$$

$$R_H = \text{Rydberg constant} = 2.18 \times 10^{-18} \text{ J}$$

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$$

### *Potentially useful formulae*

$$v = \lambda\nu$$

$$f(x) = A\sin(2\pi x/\lambda)$$

$$\lambda = h/p = h/mv$$

$$E = mc^2$$

$$E = mv^2/2$$

$$E = h\nu$$

$$H\psi = E\psi$$

$$\psi_n(x) = (2/L)^{-1/2} \sin(n\pi x/L) \quad (n = 1, 2, 3\dots)$$

$$E_n = h^2 n^2 / 8mL^2$$

$$E_n = -2.18 \times 10^{-18} Z^2 / n^2$$

# PERIODIC TABLE OF THE ELEMENTS

Group																																																					
1																	17	18																																			
1 H 1.008																	17 H 1.008	18 He 4.003																																			
2																	13 B 10.811	14 C 12.011	15 N 14.007	16 O 15.999	9 F 18.998	10 Ne 20.179																															
3	4	5	6	7	8	9	10	11	12							13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.064	17 Cl 35.453	18 Ar 39.948																																
11 Na 22.99	12 Mg 24.305	21 Sc 44.956	22 Ti 47.9	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.7	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc "(98)"	44 Ru 101.07	45 Rh 102.9	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.6	53 I 126.9	54 Xe 131.3	55 Cs 132.9	56 Ba 137.33	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.98	84 Po "(209)"	85 At "(210)"	86 Rn "(222)"
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.9	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.7	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc "(98)"	44 Ru 101.07	45 Rh 102.9	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.6	53 I 126.9	54 Xe 131.3	55 Cs 132.9	56 Ba 137.33	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.98	84 Po "(209)"	85 At "(210)"	86 Rn "(222)"
87 Fr 223	88 Ra 226.03	89 Ac# 227.03	104 Rf	105 Db {261}	106 Sg	107 Bh	108 Hs	109 Mt																																													
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																		58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 145	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 260								