

Name: _____

Student ID Number: _____

Instructions:

1. There are **3 parts to this exam!** Make sure you do them all.
2. Part 1 (multiple choice) should be answered on this page (below). Part 2 is to be answered on the exam paper. Part 3 should be answered in the exam booklets provided.
3. Allowed external materials: calculator only (any type) – no cell phones!
4. Print or write legibly!
5. Ah, memory impairment; the free prize at the bottom of every vodka bottle.
6. There are 80 points on the exam. Time allowed = 180 minutes.
7. There are a total of 12 pages including this one. The final 3 sheets of this exam paper are a periodic table, a formula sheet, and enthalpy tables. Feel free to remove them if desired.

MULTIPLE CHOICE ANSWERS - ONLY THOSE CHOICES SELECTED HERE WILL BE GRADED

Circle one answer only. The correct answer is worth full marks, incorrect answers are worth 0.

One-point multiple choice (10 points)

- | | | | | | |
|------|---|---|---|---|---|
| (1) | a | b | c | d | e |
| (2) | a | b | c | d | e |
| (3) | a | b | c | d | e |
| (4) | a | b | c | d | e |
| (5) | a | b | c | d | e |
| (6) | a | b | c | d | e |
| (7) | a | b | c | d | e |
| (8) | a | b | c | d | e |
| (9) | a | b | c | d | e |
| (10) | a | b | c | d | e |

Two-point multiple choice (20 points)

- | | | | | | |
|------|---|---|---|---|---|
| (11) | a | b | c | d | e |
| (12) | a | b | c | d | e |
| (13) | a | b | c | d | e |
| (14) | a | b | c | d | e |
| (15) | a | b | c | d | e |
| (16) | a | b | c | d | e |
| (17) | a | b | c | d | e |
| (18) | a | b | c | d | e |
| (19) | a | b | c | d | e |
| (20) | a | b | c | d | e |

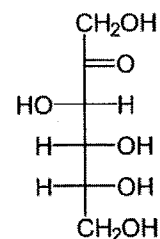
PART 1. ANSWER ON THE FRONT PAGE OF THE EXAM**One-point multiple choice.** Choose one answer only. (1 point each, 10 total)

- (1) What is the bond angle at the nitrogen in the ammonium cation (
- NH_4^+
-)?

- (a) 90° (d) 180°
 (b) 109.5° (e) 360°
 (c) 120°

- (2) This is the straight-chain form of the sugar fructose. When it cyclizes, it will become,

- (a) starch
 (b) a 5-membered ring
 (c) cellulose
 (d) a 6-membered ring
 (e) a disaccharide



- (3) Alexander Litvinenko, a Russian spy, was murdered in 2006 by poisoning with
- ^{210}Po
- . It has a half-life of 138 days and decays by
- α
- emission. What is the daughter nucleus (product)? Hint, an
- α
- particle is a
- ^4He
- nucleus.

- (a) $^{214}_{82}\text{Pb}$ (d) $^{210}_{84}\text{Po}$
 (b) $^{210}_{82}\text{Pb}$ (e) $^{206}_{84}\text{Po}$
 (c) $^{206}_{82}\text{Pb}$

- (4) The polonium that Litvinenko received was in the form polonium nitrate, which is
- $\text{Po}(\text{NO}_3)_4$
- . What is the electronic configuration of the polonium cation in this compound? Hint: nitrate is
- NO_3^-
- .

- (a) $[\text{Xe}] 5d^{10} 6s^2$ (d) $[\text{Xe}] 5d^{10} 6s^2 6p^2$
 (b) $[\text{Xe}] 5d^{10} 6s^2 6p^4$ (e) $[\text{Xe}] 5d^{10} 6p^6$
 (c) $[\text{Xe}] 5d^{10} 6p^4$

- (5) Which of the following is
- not*
- a component of DNA?

- (a) a deoxyribose sugar
 (b) a phosphate group
 (c) an amino acid
 (d) an organic base with nitrogen-containing rings
 (e) none of the above

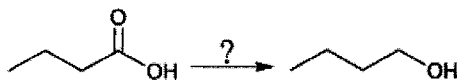
(6) Which of the following is/are a state function?

- | | |
|-----------------|--------------------------------------|
| (a) temperature | (d) mass |
| (b) enthalpy | (e) all of these are state functions |
| (c) volume | |

(7) An atom on the corner of a unit cell is shared by how many unit cells in total?

- | | |
|-------|-------|
| (a) 1 | (d) 6 |
| (b) 2 | (e) 8 |
| (c) 4 | |

(8) What reagent will give the following conversion?

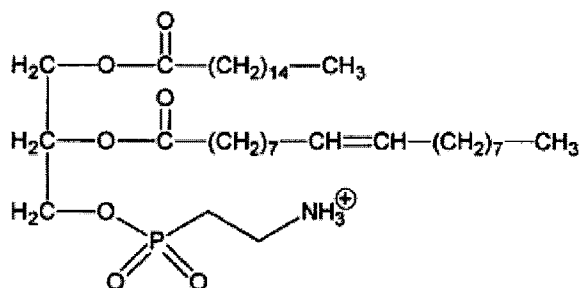


- | |
|--|
| (a) $\text{Na}_2\text{Cr}_2\text{O}_7$ |
| (b) PCC |
| (c) H_2O with an acid (H^+) |
| (d) LiAlH_4 |
| (e) CH_3OH with AlCl_3 |

(9) Which of the following is NOT a property of an ideal gas?

- | |
|---|
| (a) gasses have 0 volume |
| (b) gasses have 0 mass |
| (c) gasses have 0 intermolecular forces |
| (d) pressure is represented by molecules hitting the walls of the container |
| (e) temperature is defined as the average kinetic energy |

(10) What one term best describes this molecule?



- | |
|------------------|
| (a) fat |
| (b) oil |
| (c) phospholipid |
| (d) steroid |
| (e) protein |

Two-point multiple choice. Choose one answer only. (2 points each, 20 total)

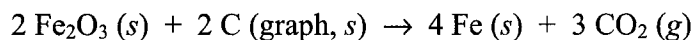
(11) How much energy is released when 10.0 g of liquid water is converted to ice at 0°C?

- | | |
|--------------|--------------|
| (a) -60.2 kJ | (d) -1.66 kJ |
| (b) -1080 kJ | (e) -3.34 kJ |
| (c) -10.8 kJ | |

(12) What is the molarity of pure water? Hint: the density of water is 1.00 g/mL.

- | | |
|-----------------------------|-----------------------------|
| (a) 5.56×10^{-3} M | (d) 1.00×10^{-3} M |
| (b) 1.00 M | (e) 55.6 M |
| (c) 16 M | |

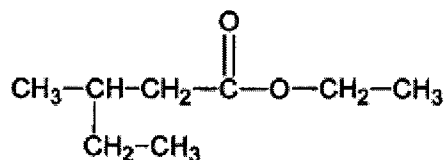
(13) Iron ore (hematite) is converted to iron metal by the reaction:



Calculate the standard enthalpy of the reaction (as written). Thermodynamic quantities are given on page 11.

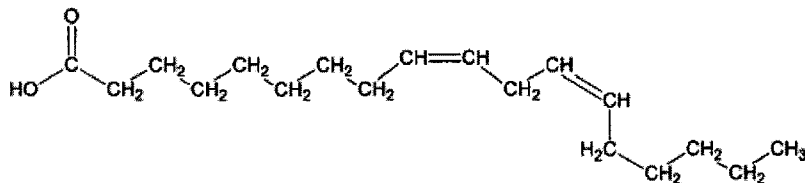
- | | |
|-------------------|-----------------|
| (a) -433 kJ/mol | (d) 433 kJ/mol |
| (b) 472 kJ/mol | (e) -472 kJ/mol |
| (c) -1220. kJ/mol | |

(14) What is the systematic name of the following compound?



- | |
|-----------------------------------|
| (a) 6-oxo-3,3-dimethyl-5-octanone |
| (b) 1-ethyl-3-methylpentanoate |
| (c) ethyl-3-methylpentanoate |
| (d) ethyl-3-ethylbutanoate |
| (e) 1,3-diethylbutanoate |

(15) Which term best describes the following fatty acid?

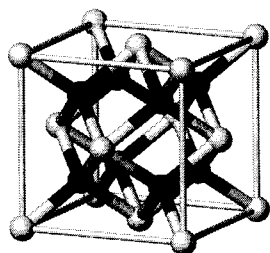


- | |
|------------------------------|
| (a) <i>trans</i> unsaturated |
| (b) <i>cis</i> unsaturated |
| (c) saturated |
| (d) polyunsaturated |
| (e) both (b) and (d) |

- (16) 112.0 g of hematite (Fe_2O_3) was converted to iron by the reaction in (13). If 64.0 g of iron was isolated, what is the percent yield?

- | | | | |
|-----|-------|-----|-------|
| (a) | 75.8% | (d) | 100% |
| (b) | 22.4% | (e) | 60.0% |
| (c) | 81.7% | | |

- (17) The unit cell for cerium(IV) oxide (ceria) is shown. How many total ions (cations + anions) are in the unit cell?

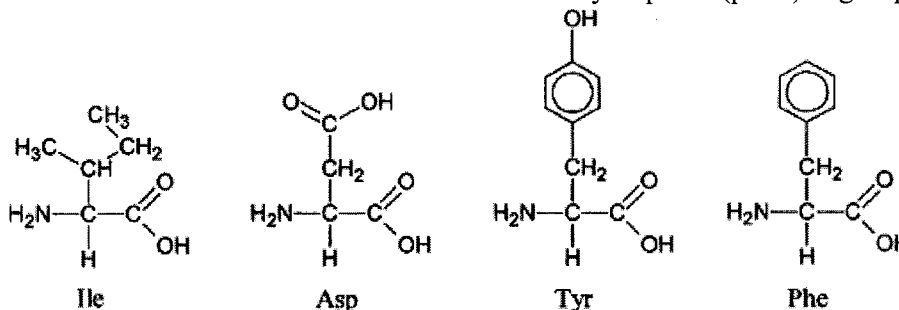


- | | |
|-----|----|
| (a) | 8 |
| (b) | 12 |
| (c) | 16 |
| (d) | 20 |
| (e) | 22 |

- (18) A 0.00281 g portion of an unknown substance was dissolved in 250.00 mL of water. 1.00 mL of this solution was found to have a concentration of $4.67 \times 10^{-5} M$. What is the molar mass of the unknown substance?

- | | | | |
|-----|--------------|-----|--------------|
| (a) | 60.2 g/mol | (d) | 3970 g/mol |
| (b) | 15 700 g/mol | (e) | 60 171 g/mol |
| (c) | 241 g/mol | | |

- (19) Four amino acids are shown. Which has/have a hydrophilic (polar) R-group?



- | | | | |
|-----|-------------|-----|-------------------|
| (a) | Tyr | (d) | Phe and Ile |
| (b) | Tyr and Asp | (e) | Phe, Tyr, and Ile |
| (c) | Asp | | |

- (20) Referring to the same amino acids (Q19), which are likely to be found in the interior of a properly folded protein?

- | | | | |
|-----|-------------|-----|-------------------|
| (a) | Tyr | (d) | Phe and Ile |
| (b) | Tyr and Asp | (e) | Phe, Tyr, and Ile |
| (c) | Asp | | |

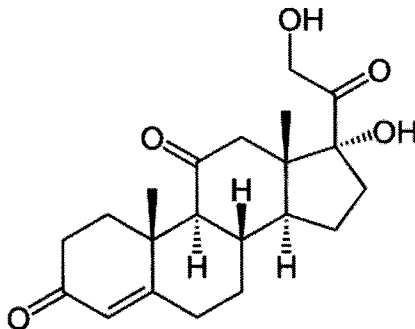
Part 2. ANSWER IN THE SPACE PROVIDED

Question 1: (3 points) This biomolecule is the bacterial protein barnase. Label the following:



- (i) an α -helix area
- (ii) a β -sheet area
- (iii) an area with no secondary structure

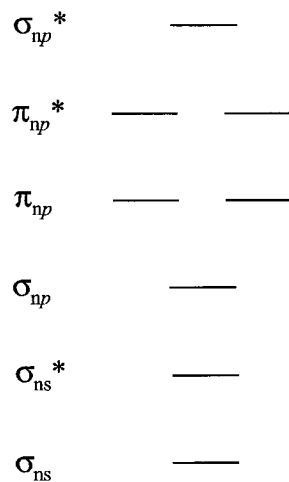
Question 2: (7 points) Cortisone, the anti-inflammatory drug, is shown. On the structure, clearly label the following (the same atom may be used more than once):



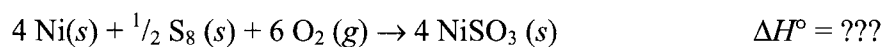
- (i) an sp^3 and an sp^2 hybridized atom
- (ii) a ketone group
- (iii) two (2) chiral centres
- (iv) label all alcohols as primary, secondary, or tertiary

Question 3: (4 points) A blank molecular orbital diagram is provided for a diatomic p-block molecule. For the molecule O_2 , fill in the appropriate number of electrons on the diagram and give the bond order (number of bonds).

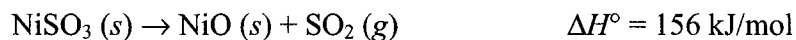
- (i) what is the bond order? _____
- (ii) based on the MO diagram, what is special about O_2 .



Question 4: (3 points) Calculate the ΔH° for generating four moles of nickel(II) sulfite,



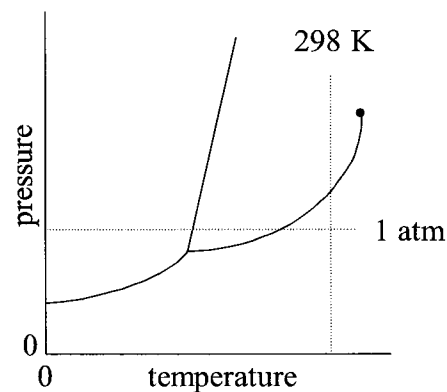
using the following reactions,



Question 5: (4 points) The phase diagram for propane is shown. Lines marking 1 atm and room temperature are given. Answer the following:

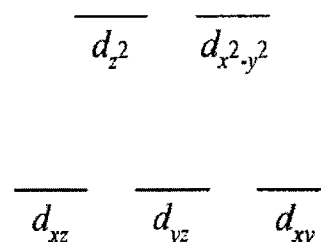
(i) what phase is propane under standard conditions?

(ii) if propane in a BBQ tank is a liquid, how is that phase maintained?

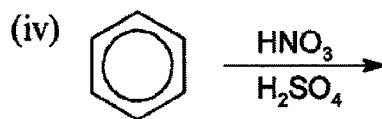
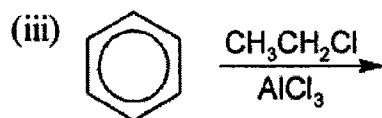
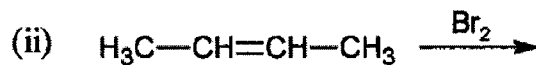
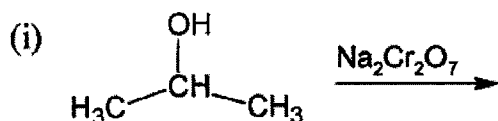


(iii) describe what phase change(s) occur when propane is cooled at 1 atm.

Question 6: (2 points) Assume Fe^{3+} is in an octahedral complex with strong field ligands (for example, $\text{Fe}(\text{CO})_6^{3+}$). Add electrons to the diagram to the right to represent the correct electron configuration for Fe^{3+} with strong-field ligands.



Question 7: (2 points each, 6 total) For **3 of the following 4 reactions**, predict the *organic* product. There is only one correct answer for each of these.



Question 8: (5 points) Balance the following redox reaction in basic conditions.



Part 3. Answer 4 of the following 6 in the BOOKLET provided (4 points each, 16 total)

- (1) What is the final temperature (of the horseshoe and the water) if a 250.00 g iron horseshoe at 1300.0 K is quenched by a blacksmith in a bucket containing 3.80 kg of water? You can assume all the heat goes into the water and that the water started at 298 K. The specific heat of iron is $0.45 \text{ J/}^\circ\text{C}\cdot\text{g}$.
- (2) The half-life of ^{210}Po is 138 days. How long will it take 85% of a sample to decay?
- (3) For the molecule SF_4 , draw: (a) the Lewis structure, (b) the VSEPR structure, and (c) determine the direction of the dipole moment (or state the molecule is non-polar).
- (4) For the following six (6) chemical species, state what the main intermolecular force is in the solid state. Your choices are, in order of bond strength: network (covalent) solid, ionic, H-bonding, dipole-dipole, and London dispersion: (a) potassium chloride, (b) graphene, (c) ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, (d) sodium nitrate, (e) propane, (f) O_3 .
- (5) Explain how the genetic code stored in DNA is used to make a protein molecule.
- (6) Cyanide poisoning causes the redox chemistry of cytochrome enzymes to stop working. Explain the mechanism by which cyanide (CN^-) destroys the function of these cytochromes.

Where is the darn HCl?



Because the limiting reagent called in sick today, the chemical reaction could not proceed as scheduled.

Appendix 1: Formula Sheet

$$PV = nRT$$

$$\frac{\text{rate}_A}{\text{rate}_B} = \frac{\bar{u}_A}{\bar{u}_B} = \frac{\sqrt{M_{mB}}}{\sqrt{M_{mA}}}$$

$$\bar{u} = \sqrt{\frac{3RT}{M_m}}$$

$$\left(P + \frac{n^2 a}{V^2}\right) \cdot (V - nb) = nRT$$

$$A = ebc$$

$$(\Delta x)(\Delta(mv)) \geq \frac{h}{4\pi}$$

$$E = h\nu (= hf)$$

$$c = \lambda\nu (= \lambda f)$$

$$\lambda = \frac{h}{mv}$$

$$E = mc^2$$

$$\Delta E = -2.178 \times 10^{-18} J \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\bar{E}_k = \frac{1}{2} m \bar{u}^2 = \frac{3}{2} \left(\frac{R}{N_A} \right) T$$

$$V \propto \frac{1}{P}$$

$$V \propto n$$

$$V \propto T$$

$$P_{\text{total}} = P_1 + P_2 + \dots$$

$$\ln \left(\frac{N_t}{N_0} \right) = -kt$$

$$t_{1/2} = \frac{\ln 2}{k}$$

$$\Delta H = q_p = \Delta E + P\Delta V$$

$$q = sm\Delta T = C_p \Delta T$$

$$\Delta E = q + w = q + Fd$$

$$\ln \left(\frac{P_{\text{vap},1}}{P_{\text{vap},2}} \right) = \frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

Constants:

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

$$c = \lambda\nu = 2.9979 \times 10^8 \text{ m/s}$$

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

$$0^\circ\text{C} = 273.15 \text{ K}$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$1 \text{ atm} = 101.325 \text{ kPa} = 760.00 \text{ Torr}$$

$$\text{mass of an electron: } 0.000549 \text{ amu (g/mol)}$$

$$\text{mass of a proton: } 1.00728 \text{ amu}$$

$$\text{mass of a neutron: } 1.008665 \text{ amu}$$

$$\text{elementary charge (e)} = 1.60218 \times 10^{-19} \text{ C}$$

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 8.314 \text{ L Pa mol}^{-1} \text{ K}^{-1} = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1} = 62.36 \text{ L Torr K}^{-1} \text{ mol}^{-1}$$

$$\text{STP} = 1 \text{ atm, } 0^\circ\text{C}$$

$$\text{standard conditions} = 1 \text{ atm, } 25^\circ\text{C, } 1 \text{ M}$$

$$\text{kilo} = 10^3 \quad \text{centi} = 10^{-2} \quad \text{milli} = 10^{-3} \quad \text{micro} = 10^{-6} \quad \text{nano} = 10^{-9} \quad \text{pico} = 10^{-12}$$

For water:

$$\Delta H_{\text{fusion}} = 6.02 \text{ kJ/mol}$$

$$\Delta H_{\text{vaporization}} = 40.7 \text{ kJ/mol}$$

$$\text{specific heat capacities (J}^\circ\text{C} \cdot \text{g)}:$$

$$s_{\text{ice}} = 2.11$$

$$s_{\text{liquid}} = 4.18$$

$$s_{\text{steam}} = 2.08$$

Thermodynamic Tables

Substance and State	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	ΔS° (J/K · mol)	Substance and State	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	ΔS° (J/K · mol)
Carbon				Iron			
C(s) (graphite)	0	0	6	Fe(s)	0	0	27
C(s) (diamond)	2	3	2	Fe ₃ C(s)	21	15	108
CO(g)	-110.5	-137	198	Fe _{0.95} O(s) (wustite)	-264	-240	59
CO ₂ (g)	-393.5	-394	214	FeO	-272	-255	61
CH ₄ (g)	-75	-51	186	Fe ₃ O ₄ (s) (magnetite)	-1117	-1013	146
CH ₃ OH(g)	-201	-163	240	Fe ₂ O ₃ (s) (hematite)	-826	-740	90
CH ₃ OH(l)	-239	-166	127	FeS(s)	-95	-97	67
H ₂ CO(g)	-116	-110	219	FeS ₂ (s)	-178	-166	53
HCOOH(g)	-363	-351	249	FeSO ₄ (s)	-929	-825	121
HCN(g)	135.1	125	202	Lead			
C ₂ H ₂ (g)	227	209	201	Pb(s)	0	0	65
C ₂ H ₄ (g)	52	68	219	PbO ₂ (s)	-277	-217	69
CH ₃ CHO(g)	-166	-129	250	PbS(s)	-100	-99	91
C ₂ H ₅ OH(l)	-278	-175	161				
C ₂ H ₆ (g)	-84.7	-32.9	229.5				

Single Bonds				Multiple Bonds			
H-H	432	N-H	391	I-I	149	C=C	614
H-F	565	N-N	160	I-Cl	208	C≡C	839
H-Cl	427	N-F	272	I-Br	175	O=O	495
H-Br	363	N-Cl	200			C=O *	745
H-I	295	N-Br	243	S-H	347	C≡O	1072
		N-O	201	S-F	327	N=O	607
C-H	413	O-H	467	S-Cl	253	N=N	418
C-C	347	O-O	146	S-Br	218	N≡N	941
C-N	305	O-F	190	S-S	266	C≡N	891
C-O	358	O-Cl	203			C=N	615
C-F	485	O-I	234	Si-Si	340		
C-Cl	339			Si-H	393		
C-Br	276	F-F	154	Si-C	360		
C-I	240	F-Cl	253	Si-O	452		
C-S	259	F-Br	237				

The Periodic Table of the Elements (with Electronegativities)

Element name		Mercury		Atomic #	
		80		Hg	
Symbol		200.59		Avg. Mass	
Electronegativity		1.9			

Group	1	2	3	4	5	6	7	8	9	10	11	12																						
Period 1	H 1.01 1	He 4.00 2																																
Period 2	Li 6.94 3	Be 9.01 4	B 10.81 5	C 12.01 6	N 14.01 7	O 16.00 8	F 19.00 9	Ne 20.18 10					Ar 39.96 18																					
Period 3	Na 22.99 11	Mg 24.31 12	Al 26.98 13	Si 28.09 14	P 30.97 15	S 32.07 16	Cl 35.45 17	Ar 39.96 18					Kr 83.80 36																					
Period 4	K 39.10 19	Ca 40.08 20	Sc 44.96 21	Ti 47.88 22	V 50.94 23	Cr 52.00 24	Mn 54.94 25	Fe 55.85 26	Co 58.93 27	Ni 58.69 28	Cu 63.55 29	Zn 65.39 30	Ga 69.72 31	Ge 72.64 32	As 74.92 33	Se 78.96 34	Br 79.90 35	Kr 83.80 36																
Period 5	Rb 85.47 37	Sr 87.62 38	Y 88.91 39	Zr 91.22 40	Nb 92.91 41	Mo 95.94 42	Tc (98) 98	Ru 101.07 44	Rh 102.91 45	Pd 106.42 46	Ag 107.87 47	Cd 112.41 48	In 114.82 49	Sn 118.71 50	Sb 121.76 51	Te 127.60 52	I 126.90 53	Xe 131.29 54	Rn 222 86															
Period 6	Cs 132.91 55	Ba 137.33 56	La 138.91 57	Ce 140.12 58	Pr 140.91 59	Nd 144.24 60	Pm (145) 61	Sm 150.36 62	Eu 151.97 63	Gd 157.25 64	Tb 158.93 65	Dy 162.50 66	Ho 164.93 67	Er 167.26 68	Tm 168.93 69	Yb 173.04 70	Lu 174.97 71	Hf 178.49 72	Ta 180.95 73	W 183.84 74	Re 186.21 75	Os 190.23 76	Ir 192.22 77	Pt 195.08 78	Au 196.97 79	Hg 200.59 80	Tl 204.38 81	Pb 207.20 82	Bi 208.98 83	Po 209 84	At (210) 85	Rn (222) 86		
Period 7	Fr (223) 87	Ra (226) 88	Ac (227) 89	Th (232) 90	Pa (231) 91	U (238) 92	Np (237) 93	Pu (244) 94	Americanium (243) 95	Berkelium (247) 96	Californium (251) 97	Einsteinium (252) 98	Fermium (257) 99	Mendelevium (258) 100	Nobelium (259) 101	Lutetium (262) 102	Hassium (265) 103	Meitnerium (266) 104	Darmstadtium (269) 105	Roentgenium (271) 106	Copernicium (285) 112	Nihonium (286) 113	Flerovium (289) 114	Moscovium (293) 115	Livermorium (293) 116	Tennessine (294) 117	Oganesson (294) 118	Uuo (294) 118	Uuh (293) 116	Uup (286) 115	Uuq (289) 114	Uuf (284) 113	Uug (288) 112	Uuo (294) 118

Alkali metals
 Alkaline earth metals
 Transition metals
 Lanthanides
 Actinides
 Other metals
 Metalloids (semi-metal)
 Nonmetals
 Halogens
 Noble gases

Group	13	14	15	16	17	18
Period 13	B 10.81 5	C 12.01 6	N 14.01 7	O 16.00 8	F 19.00 9	Ne 20.18 10
Period 14	Al 26.98 13	Si 28.09 14	P 30.97 15	S 32.07 16	Cl 35.45 17	Ar 39.96 18
Period 15	Ga 69.72 31	Ge 72.64 32	As 74.92 33	Se 78.96 34	Br 79.90 35	Kr 83.80 36
Period 16	In 114.82 49	Sn 118.71 50	Sb 121.76 51	Te 127.60 52	I 126.90 53	Xe 131.29 54
Period 17	Tl 204.38 81	Pb 207.20 82	Bi 208.98 83	Po 209 84	At (210) 85	Rn (222) 86
Period 18	Uuo (294) 118	Uuh (293) 116	Uup (286) 115	Uuq (289) 114	Uuf (284) 113	Uug (288) 112

*lanthanides

**actinides