2022 Fall Semester Midterm Examination

For General Chemistry I

Date: Oct 19 (Wed), Time Limit: 19:00 ~ 21:00

Write down your information neatly in the space provided below; print your Student ID in the upper right corner of every page.

Professor Name	Class	Student I.D. Number	Name

Problem	points	Problem	points	TOTAL pts
1	/10	**6**	/14	
2	/10	**7**	/8	
3	/12	**8**	/10	**/100**
4	/12	**9**	/12	
5	/12			

** This paper consists of 20 sheets with 9 problems (***page 18 - 19***: Equation, constants & periodic table, ***page 20***: claim form). Please check all page numbers before taking the exam. Write down your work and answers in the Answer sheet. Please write down the unit of your answer when applicable. You will get 30% deduction for a missing unit.

NOTICE: SCHEDULES on RETURN and CLAIM of the MARKED EXAM PAPER.
(채점 답안지 분배 및 이의신청 일정)

1. Period, Location and Procedure

1-1) For students who took the off-line Examination

0 Return and Claim Period: **October 24 (Mon, 20:00 ~ 21:00, 1 hr)**

The claim is permitted only on this period. Keep that in mind!

0 Location: Each designated room of Creative Learning Bldg. (E11)

Class	Room(E11)	Class	Room(E11)
A	201	**B**	202

0 Procedure

Rule 1: Students cannot bring their writing tools into the rooms (Use a pen only provided by TA)

Rule 2: With or without claim, you must submit the paper back to TA. (Do not go out of the room with it)

If you have any claims on it, write them on the claim form and attach it to the top of the exam paper with a stapler. Give them to your TA.

WARNING!!

If you deliberately alter any original answers or insert something on your marked paper to achieve a better grade, you will get a F grade for this course. Or if you don't keep the rules above, we will regard it as a kind of cheating and give you 0 point. So please don't cheat.

2. Final Confirmation

1) Period: ***October 27(Thu) ~ 28(Fri)***

2) Procedure: During this period, you can check final score of the examination *on the website* again.

(No additional corrections. If no change in your score after reasoning, the claims were not accepted.)

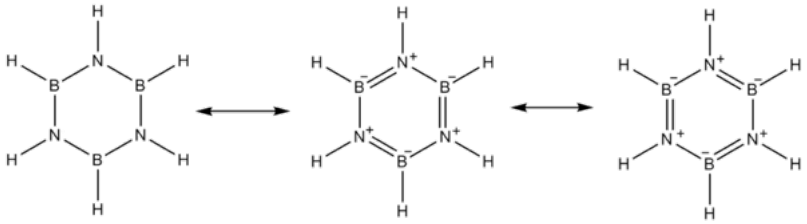
***** For further information, please visit General Chemistry website at www.gencheminkaist.pe.kr***

1. (total 10 pts)

Borazine is an inorganic compound with a chemical formular $B_3N_3H_6$. Experimental data suggested that the compound contains three types of covalent bonding connectivity, *i.e.* B-N, B-H, and N-H bonds. Spectroscopic measurements revealed that the B-N bonds formed a 6-membered ring and their bond lengths were measured as 1.44 Å. Assuming typical B-N lengths of single and double bonds are 1.68 Å and 1.41 Å, answer the following questions.

(a) Draw a Lewis diagram of borazine and assign formal charges for B and N atoms. (4 pts)

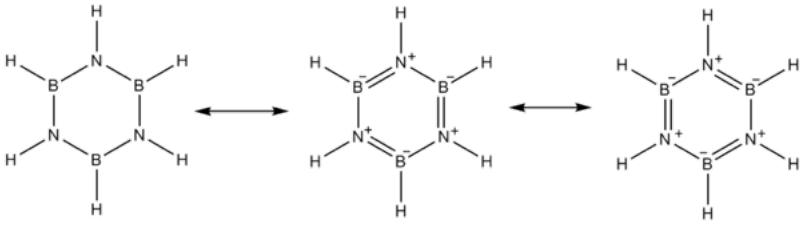
(Answer) (among them)



Formal charges of B	0	-1	+1	(2pts)
Formal charges of N	0	+1	-1	(2pts)

(b) Draw all possible resonance structures of borazine. (3 pts)

(Answer)



(c) Among the resonance structures from (b), which form(s) might have the highest contribution to the actual molecular geometry? Explain why. (3 pts)

(Answer) Experimental bond length (1.44 Å) is closer to the typical B-N double bond (1.41 Å).

2. (total 10 pts)

X is an element located in the third row of the the periodic table and has the following ionization energy trends. Answer the following questions.

	IE_1	IE_2	IE_3	IE_4	IE_5	IE_6	IE_7	IE_8
X	10.36	23.33	34.83	47.30	72.68	88.05	280.93	328.23

Ionization energy is given as eV.

(a) What is element X? Rationalize your answer (3 pts)

(b) Element X reacts with F to form a compound XF_4. Draw a Lewis structure for this species. (3 pts)

(c) Provide all possible geometries based on a SN number. Choose a more stable structure and justify your answer (4 pts)

<Answer #1>

(a)

X = S (sulfur), It has 6 valence electrons because IE7 significantly increases than IE6.

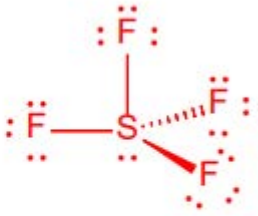
(b)

(Do not consider geometry in this problem.)

(c)

Each 2 pts

Seesaw shape



Trigonal Pyramidal

Seesaw shape is more stable because repulsion between S-F bonds and electron lone pair is smaller than trigonal pyramidal structure.

3. (total 12 pts)

A wavefunction $\psi_{nlm}(r,\theta,\phi)$ for a one-electron atom in the state (n, l, m) is called an orbital. Given that the total wavefunction of hydrogen is a product of the radial part ($R_{nl}(r)$) and the angular part ($Y_{lm}(\theta,\phi)$), fill in the blanks of the following table.

$$\psi_{nlm}(r,\theta,\phi) = \begin{cases} R_{nl}(r) \\ Y_{lm}(\theta,\phi) \end{cases}$$

$\sigma = \frac{Zr}{a_0}$, a_0 = 0.529 Å, Z=1 for hydrogen atom.

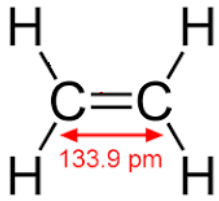
Orbital	n	l	m	Total # of nodes
$\psi_{nlm}(r,\theta,\phi) = \begin{cases} 2\left(\frac{Z}{a_0}\right)^{3/2}\exp(-\sigma) \\ \left(\frac{1}{4\pi}\right)^{1/2} \end{cases}$				
$\psi_{nlm}(r,\theta,\phi) = \begin{cases} \frac{2}{81\sqrt{3}}\left(\frac{Z}{a_0}\right)^{3/2}(27-18\sigma+2\sigma^2)\exp(-\sigma/3) \\ \left(\frac{1}{4\pi}\right)^{1/2} \end{cases}$				
$\psi_{nlm}(r,\theta,\phi) = \begin{cases} \frac{4}{81\sqrt{6}}\left(\frac{Z}{a_0}\right)^{\frac{3}{2}}(6\sigma+2\sigma^2)\exp(-\sigma/3) \\ \left(\frac{3}{4\pi}\right)^{1/2}\cos\theta \end{cases}$				

(Answer) 1 pt for each

Orbital	n	l	m	Total # of nodes
$\psi_{nlm}(r,\theta,\phi) = \begin{cases} 2\left(\frac{Z}{a_0}\right)^{3/2}\exp(-\sigma) \\ \left(\frac{1}{4\pi}\right)^{1/2} \end{cases}$	1	0	0	0
$\psi_{nlm}(r,\theta,\phi) = \begin{cases} \frac{2}{81\sqrt{3}}\left(\frac{Z}{a_0}\right)^{3/2}(27-18\sigma+2\sigma^2)\exp(-\sigma/3) \\ \left(\frac{1}{4\pi}\right)^{1/2} \end{cases}$	3	0	0	2
$\psi_{nlm}(r,\theta,\phi) = \begin{cases} \frac{4}{81\sqrt{6}}\left(\frac{Z}{a_0}\right)^{\frac{3}{2}}(6\sigma+2\sigma^2)\exp(-\sigma/3) \\ \left(\frac{3}{4\pi}\right)^{1/2}\cos\theta \end{cases}$	3	1	0	2

4. (total 12 pts)

In the ethylene molecule, there is a double bond between carbon atoms, represented by C=C. The length of bond is about 1.34 Å. The motion of an electron in this bond can be considered crudely as motion in a one-dimensional box.



(a) Calculate the energy of an electron in ground state if it is confined to move in a one-dimensional box of length 1.34 Å. The energy level of the electron in a box is $E_n = \frac{n^2h^2}{8mL^2}$ (2 pts)

(b) Calculate the wavelength of light necessary to excite the electron from n=2 state to n=4 state. (4 pts)

(c) The normalized wave function for a particle in a one-dimensional box, in which the potential energy is 0, is $\psi(x) = \sqrt{(2/L)}\ sin(n\pi x/L)$, where L is the length of the box. If the electron in this double bond could follow the motion in a one-dimensional box (L = 1.34 Å), and the electron is in its n=1 state, what is the probability that the electron will lie between x=0 and x= 0.67 Å (=L/2)? (6 pts)

(You can refer to the following expression… $\int sin^2(ax)\,dx = \frac{x}{2} - \frac{sin(2ax)}{4a}$)

<Answer #3>

(a)

$$E_1 = \frac{1^2 \cdot h^2}{8mL^2} = \frac{1 \times (6.626 \times 10^{-34} J\ s^{-1})^2}{8 \times (9.109 \times 10^{-31}\ kg) \times (1.34 \times 10^{-10}\ m)^2} = 3.36 \times 10^{-18} J$$

부분점수 없음

(b)

$$E_4 - E_2 = (4^2 - 2^2) \cdot \frac{h^2}{8mL^2} = \frac{12h^2}{8mL^2} = \frac{12 \times (6.626 \times 10^{-34} J\ s^{-1})^2}{8 \times (9.109 \times 10^{-31}\ kg) \times (1.34 \times 10^{-10}\ m)^2}$$

$$= 4.03 \times 10^{-17} J = h\frac{c}{\lambda}$$

$$\lambda = \frac{hc}{E_4 - E_2} = \frac{(6.626 \times 10^{-34} J\ s^{-1}) \times (2.998 \times 10^8\ m\ s^{-1})}{4.03 \times 10^{-17} J} = 4.93\ nm$$

for this operation, 4.93 nm, which is in the ultraviolet region of the spectrum is needed.

식과 답이 맞으면 4점, 식의 전개만 맞으면 2점

(c)

$$\psi(x)_1 = \sqrt{\left(\frac{2}{L}\right)}\, sin\left(\frac{\pi x}{L}\right), (L = 1.34\ \text{Å})$$

$$probability = \int_0^{\frac{L}{2}} \psi(x)_1\, dx = \int_0^{\frac{L}{2}} \left\{\sqrt{\left(\frac{2}{L}\right)}\, sin\left(\frac{\pi x}{L}\right)\right\}^2 dx = \int_0^{\frac{L}{2}} \frac{2}{L} sin^2\left(\frac{\pi x}{L}\right) dx$$

$$probability = \frac{2}{L}\left|sin^2\left(\frac{\pi x}{L}\right)\right|_{x=0}^{x=\frac{L}{2}} = \frac{2}{L}\left|\frac{x}{2} - \frac{sin(2\frac{\pi x}{L})}{4\frac{\pi}{L}}\right|_{x=0}^{x=\frac{L}{2}} = \frac{2}{L}\left(\frac{L}{4} - 0 - 0 + 0\right)$$

$$= \frac{1}{2}$$

확률을 구하기 위해 파동함수를 제곱하여 적분하는 식(또는 말로 설명)이 나오면 2점,

확률을 구하는 식과 주어진 적분식을 식을 활용하면 4점,

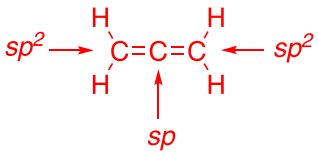
답만 맞추면 3점

5. (total 12 pts)

Allene is an organic compound with a molecular formular of $H_2C=C=CH_2$. Valence bond theory allows prediction of its three-dimensional molecular geometry.

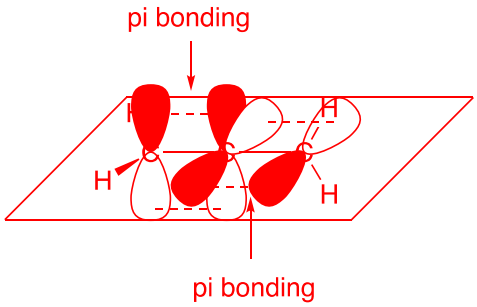
(a) Draw a Lewis diagram of allene. What hybridization do you expect each carbon to have? (5 pts)

(Answer) 2pt for the structure, 1 pt each for the hybridization



(b) Draw *p* orbital(s) of carbon atoms if there is any, and specify corresponding π bond(s) in a three-dimensional space. (5 pts)

(Answer)

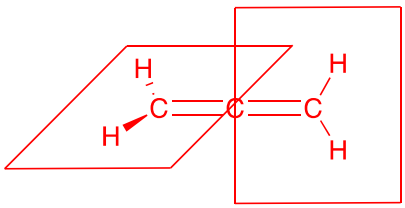


Two phases (+ and -) should be specified in drawing p orbitals, otherwise -0.5 pt for each p orbital. Two *p* orbitals in the central carbon should be perpendicular to each other.

(c) Is the molecule planar? Explain why. (2 pts)

(Answer)

Allene is not planar. Two *p* orbitals on the *sp*-hybridized central carbon are perpendicular to each other. Consequently, two π bondings are perpendicular.



6. (total 14 pts)

(a) Predict a ground-state configuration, bond order and paramagnetism for F_2^+, F_2 and F_2^-. (6 pts)

(b) Which atom or ion in each pair has the smaller radius? Explain why. (8 pts)

(1) Li, Li^+ (2) F, F^- (3) O^{2-}, F^- (4) Na^+, Mg^{2+}

(Sol)

a) (-0.5 pt for each wrong answer)

	F_2^+	F_2	F_2^-
σ^*_{pz}	-	-	↑
π^*_{2p}	↑↓ ↑	↑↓ ↑↓	↑↓ ↑↓
π_{2p}	↑↓ ↑↓	↑↓ ↑↓	↑↓ ↑↓
σ_{2pz}	↑↓	↑↓	↑↓
σ^*_{2s}	↑↓	↑↓	↑↓
σ_{2s}	↑↓	↑↓	↑↓

F_2^+ and F_2^- are paramagnetic, one unpaired electron in each. F_2 is dia-magnetic. For the bond orders, we have:

F_2^+ 1/2(8-5) = 3/2

F_2 1/2(8-6) = 1

F_2^- 1/2(8-7) = 1/2

b) 2 pts each

(1) Li and Li^+, simply an atom and its cation. Li^+ is smaller than Li.

(2) F and F^-, atom and anion. F is smaller than F^-.

(3) O^{2-} and F^-, each has neon configuration $2s^2sp^6$. The oxygen nucleus has 8 protons, whereas the fluorine has 9. F^- has smaller radius.

(4) Na^+ and Mg^{2+}, isoelectronic cations. The magnesium nucleus, with one more proton than sodium, exerts the stronger pull. Mg^{2+} is smaller than Na^+.

7. (total 8 pts)

In a laboratory, 16.0 g of methane gas (CH_4) was charged in a 1.0 L steel vessel at 0 ^oC. Van der Waals constants of CH_4 are 4.170 atm L^2 mol^{-2} and 0.04278 L mol^{-1} for a and b, respectively. Answer the following questions.

(a) Calculate the pressure of the ideal gas using the ideal gas law. (2 pts)

(Answer)

Mw of CH_4 is 16.0 g/mol, thus n= 16.0 g/ (16.0 g/mol) = 1.0 mol.

From the ideal gas law, P = nRT / V = (1.0 mol) (0.082 atm L mol-1 K-1) (273.15 K) / (1.0 L) = 22.4 atm

(b) Calculate the pressure of the real gas using the van der Waals equation. (3 pts)

(Answer)

From the van der Waals equation,

$(P+a(n/V)^2)(V-nb) = nRT$

P + a(n/V)2 = nRT/(V-nb)

$P + 4.170\ (1.0/1.0)^2 = (1.0)(0.082)(273.15)/(1.0 – (1.0)(0.04278)) = 23.40$ atm

P = 19.2 atm

(c) The same mole of H_2 real gas was charged in another 1.0 L vessel at the same temperature. Predict if the pressure of H_2 is higher, lower, or identical to the aforementioned methane vessel. Explain why. (3 pts)

(Answer)

From (a) and (b), it is clear that the attractive force of methane dominates over repulsive interaction under the conditions. Attractive force of H_2 is weaker than that of CH_4 due to weaker intermolecular force (induced dipole-induced dipole force, or van der Waals force), pressure of H_2 vessel might be higher than that of CH_4.

8. (total 10 pts)

Some water starts out at a temperature of 298 K and a pressure of 1 atm. It is compressed to 500 atm at constant temperature, and then heated to 750 K at constant pressure. Next, it is decompressed at 750 K back to 1 atm and finally cooled to 400 K at constant pressure.

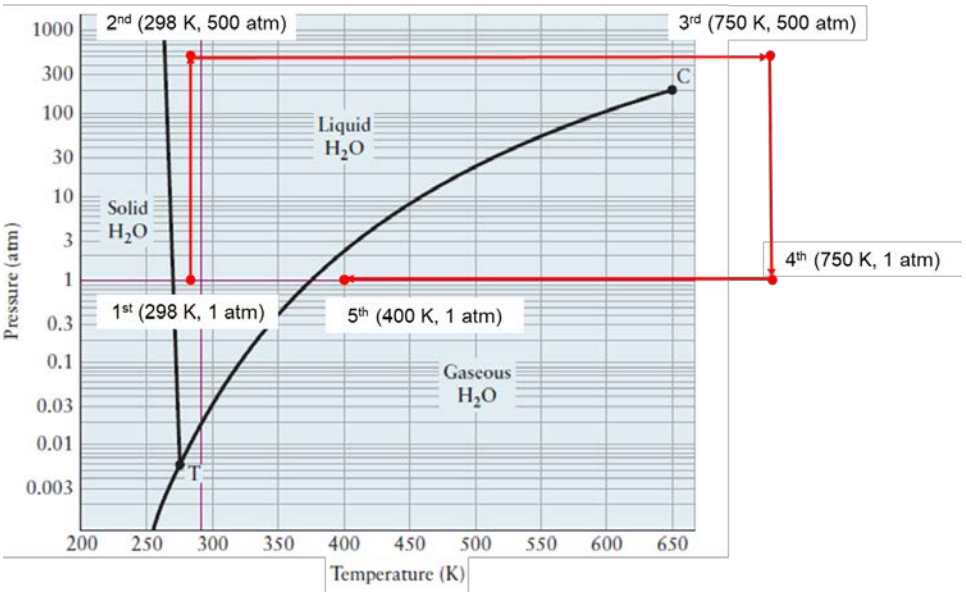
Water	P (atm)	T (K)
Triple point	0.0060	0.01
Critical point	217.75	374
Normal boiling point	1.000	100
Normal melting point	1.000	0.00

(a) Draw the phase diagram for water by using the above information, and also draw the abovementioned operations. What was the state of the water at start and end of the experiment? (6 pts)

(b) Did any phase transitions occur during the four steps described? If so, at what temperature and pressure did they occur? (4 pts)

<Answer>

(a)



Start: liquid, end: gas according to phase diagram

상평형도를 올바르게 그리면 +2, 상평형도에 각 실험의 조작을 올바르게 기입하면 +2, 처음과 마지막 상태를 올바르게 기입하면 각+1

(b)

No phase transition occurs. The change from liquid to supercritical fluid is smooth and gradual and the subsequent change from supercritical fluid to gas is also continuous. There is no abrupt change in density or other physical properties and therefore no phase transition.

상전이의 정의에 근거하여 상전이가 없다고 하는 경우 +4

답만 맞춘 경우 +2

9. (total 12 pts)

Multiple choice:

9-1) At a fixed temperature and pressure 4.5 L of $F_2(g)$ and 1.5 L of $Cl_2(g)$ react completely to from 3.0 L of a new gas. What is the formula of the new gas?

a. ClF

b. Cl_2F_2

c. ClF_3

d. Cl_2F_6

e. Cl_3F

ANS: C (2 pts each)

9-2) At room temperature which of the following gases will have the fastest average velocity?

a. H_2

b. He

c. N_2

d. O_2

e. it depends on the pressure and volume

ANS: A

9-3) Which of the following in gases is least likely to behave ideally?

a. He

b. Ne

c. N_2

d. H_2

e. NH_3

ANS: E

9-4) Generally if a liquid has stronger intermolecular attractions it will have

a. a higher viscosity.

b. a higher vapor pressure.

c. a higher boiling point.

d. a & b

e. b & c

f. a & c

g. all of the above

ANS: F

9-5) Which of the following is true for a liquid at its equilibrium vapor pressure?

a. the rate of evaporation exceeds that of condensation.

b. the rate of condensation exceeds that of evaporation.

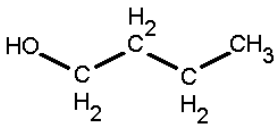
c. the rate of condensation and evaporation are the same.

d. the system is neither evaporating nor condensing.

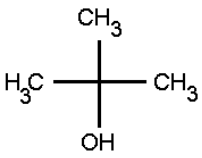
e. the system is at the critical point.

ANS: C

9-6) Which do you think has a higher boiling point, n-butanol or tert-butanol?



n-butanol



tert-butanol

a. n-butanol because it forms stronger hydrogen bonds.

b. tert-butanol because it forms stronger hydrogen bonds.

c. n-butanol because the linear molecule allows for greater dispersion forces.

d. tert-butanol because the tetrahedral molecule allows for greater dispersion forces.

e. they will be exactly the same.

ANS: C

Physical Constants

Avogadro's number	N_A = 6.02214179 x 10^{23} mol^{-1}
Bohr radius	a_0 = 0.52917720859 Å = 5.2917720859 x 10^{-11} m
Boltzmann's constant	K_B = 1.3806504 x 10^{-23} J K^{-1}
Electronic charge	e = 1.602176487 x 10^{-19} C
Faraday constant	F = 96485.3399 C mol^{-1}
Masses of fundamental particles:	
Electron	m_e = 9.10938215 x 10^{-31} kg
Proton	m_P = 1.672621637 x 10^{-27} kg
Neutron	m_n = 1.674927211 x 10^{-27} kg
Permittivity of vacuum	ε_0 = 8.854187817 x 10^{-12} C^{-2} J^{-1} m^{-1}
Planck's constant	h = 6.62606896 x 10^{-34} J s
Ratio of proton mass to electron mass	m_P / m_e = 1836.15267247
Speed of light in a vacuum	c = 2.99792458 x 10^8 m s^{-1} (exactly)
Standard acceleration of terrestrial gravity	g = 9.80665 m s^{-2} (exactly)
Universal gas constant	R = 8.314472 J mol^{-1} K^{-1} = 0.0820574 L atm mol^{-1} K^{-1}

Values are taken from the 2006 CODATA recommended values,
as listed by the National Institute of Standards and Technology.

Conversion factors

Ångström	1 Å= 10^{-10} m
Atomic mass unit	1 u = 1.660538782 x 10^{-27} kg
	1 u = 1.492417830 x 10^{-10} J = 931.494028 MeV (energy equivalent form $E = mc^2$)
Calorie	1 cal = 4.184 J (exactly)
Electron volt	1 eV = 1.602177 x 10^{-19} J = 96.485335 kJ mol^{-1}
Foot	1 ft = 12 in = 0.3048 m (exactly)
Gallon (U. S.)	1 gallon = 4 quarts = 3.785412 L (exactly)
Liter	1 L = 10^{-3} m^3 = 10^3 cm^3 (exactly)
Liter-atmosphere	1 L atm = 101.325 J (exactly)
Metric ton	1 t = 1000 kg (exactly)
Pound	1 lb = 16 oz = 0.4539237 kg (exactly)
Rydberg	1 Ry = 2.17987197 x 10^{-18}J = 1312.7136 kJ mol^{-1} = 13.60569193 eV
Standard atmosphere	1 atm = 1.01325 x 10^5 Pa = 1.01325 x 10^5 kg m^{-1} s^{-2} (exactly)
Torr	1 torr = 133.3224 Pa

PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/

GROUP NUMBERS IUPAC RECOMMENDATION (1985) — GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986)

ATOMIC NUMBER — SYMBOL — ELEMENT NAME — RELATIVE ATOMIC MASS (1)

PERIOD	1 IA												13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 H HYDROGEN	2 IIA																2 4.0026 He HELIUM
2	3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULPHUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.39 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.80 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.94 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (261) Rf RUTHERFORDIUM	105 (262) Db DUBNIUM	106 (266) Sg SEABORGIUM	107 (264) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (268) Mt MEITNERIUM	110 (281) Uun UNUNNILIUM	111 (272) Uuu UNUNUNIUM	112 (285) Uub UNUNBIUM		114 (289) Uuq UNUNQUADIUM				

LANTHANIDE 6	57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.04 Yb YTTERBIUM	71 174.97 Lu LUTETIUM
ACTINIDE 7	89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)

Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

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