Name: ____________________ Student number: ______________

Chemistry 1A03 **Test 1** **Oct 2, 2015**

McMaster University **VERSION 1**

Instructors: D. Brock, G. Goward, A. Hitchcock, L. Davis

Duration: 90 minutes

This test contains 16 numbered pages printed on both sides. There are **20** multiple-choice questions appearing on pages numbered 3 to 12. Pages 13 and 14 are extra space for rough work. Page 15 includes some useful data and equations, and there is a periodic table on page 16. You may tear off the last page to view the periodic table and the data provided.

You must enter your name and student number on this question sheet, as well as on the answer sheet. Your invigilator will be checking your student card for identification.
You are responsible for ensuring that your copy of the question paper is complete. Bring any discrepancy to the attention of your invigilator.

All questions are worth 2 marks - the total marks available are 40. There is **no** penalty for incorrect answers.
BE SURE TO ENTER THE CORRECT VERSION OF YOUR TEST (shown near the top of page 1), IN THE SPACE PROVIDED ON THE ANSWER SHEET.

ANSWER ALL QUESTIONS ON THE ANSWER SHEET, IN PENCIL.
Instructions for entering multiple-choice answers are given on page 2.
SELECT ONE AND ONLY ONE ANSWER FOR EACH QUESTION from the answers **(A)** through **(E). No work written on the question sheets will be marked**. The question sheets may be collected and reviewed in cases of suspected academic dishonesty.

Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, *etc.*) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem please ask the invigilator to deal with it for you. Do not make contact with other students directly. Try to keep your eyes on your own paper – looking around the room may be interpreted as an attempt to copy.

Only Casio FX 991 electronic calculators may be used; but they must NOT be transferred between students. Use of any aids other than those provided, is not allowed.

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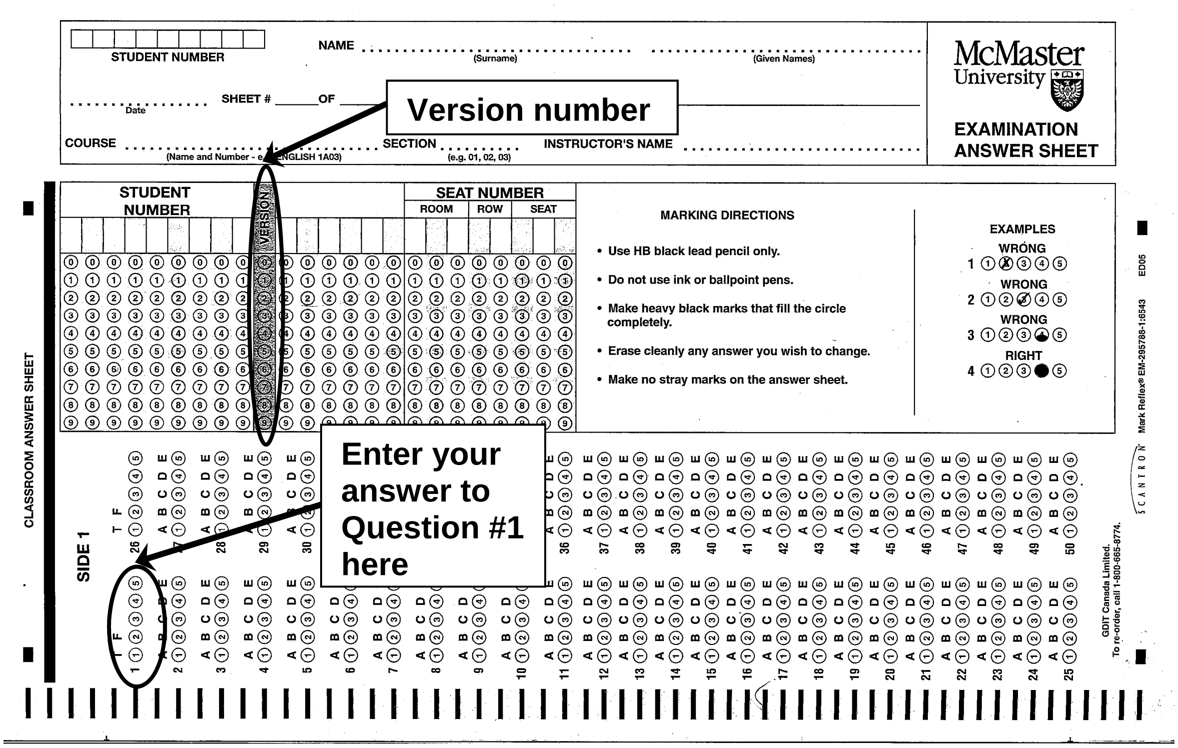
OMR EXAMINATION – STUDENT INSTRUCTIONS

NOTE: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED: YOUT EXAMINIATION RESULT DEPENDS UPON PROPER ATTENTION TO THESE INSTRUCTIONS.

The scanner, which reads the sheets, senses the bubble shaded areas by their non-reflection of light. A heavy mark must be made, completely filling the circular bubble, with an HB pencil. Marks made with a pen will **NOT** be sensed. Erasures must be thorough or the scanner will still sense a mark. Do **NOT** use correction fluid on the sheets. Do **NOT** put any unnecessary marks or writing on the sheet.

1. On SIDE 1 (**red side**) of the form, in the top box, *in pen*, print your student number, name, course name, and the date in the spaces provided. Then you **MUST** write your signature, in the space marked SIGNATURE.
2. In the second box, *with a pencil*, mark your **student number** in the space provided. If your student number does **NOT** begin with a 4, put "00" before your student number. Then fill in the corresponding bubble numbers underneath.
3. Do NOT put in a leading zero when bubbling in your **exam version number**.
4. Answers: mark only **ONE** choice from the alternatives (A,B,C,D,E) provided for each question. The question number is to the left of the bubbles. Make sure that the number of the question on the scan sheet is the same as the number on the test paper.
5. Pay particular attention to the marking directions on the form.
6. Begin answering the question using the first set of bubbles, marked "1".



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1. What is the **atomic number** of sodium?

   A) 23
   B) 32
   C) 11
   D) 12
   E) 16

2. The manufacture of pure silicon used in solar cells is described by the ***unbalanced*** reaction below. If 0.275 **mol** of pure $SiCl_4(l)$ are reacted with 9.02 **g** of Mg(s), what is the **mass** (in grams) of silicon produced?

   $SiCl_4(l) + Mg(s) \rightarrow Si(s) + MgCl_2(s)$

   A) 6.78
   B) 5.21
   C) 9.27
   D) 4.91
   E) 8.62

$SiCl_4(l) + 2Mg(s) \rightarrow Si(s) + 2MgCl_2(s)$

Moles of Mg(s) = mass of Mg/MM_{Mg} divided by coefficient

$= 9.02 \text{ g} / 24.305 \text{ g mol}^{-1} = 0.371_{117054} \text{ mol } (0.185_{558527})$

Moles of $SiCl_4(l)$ = 0.275

Therefore Mg(s) is limiting based on the 2:1 stoichimoetry…

moles of Si produced = moles of Mg(s)/2 × 1

$= 0.371_{117054} \text{ mol}/2 \times 1 = 0.185_{558527} \text{ mol}$

Mass of Si = moles of Si × $MM_{Si} = 0.185_{558527} \times 28.086 = 5.21$ g

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3. A 100.0 mL nickel container is filled with 5.00×10^{-3} mol of Xe(g) and 4.07×10^{-2} mol of $F_2(g)$ at 25.0 ^oC. After reacting the gases, $XeF_6(g)$ was produced. What was the **final total pressure (in bar)** in the vessel at 25.0 ^oC?

A) 7.62
B) 11.3
C) 4.29
D) 4.97
E) 7.01

	Xe(g)	+ 3F₂(g)	→ XeF₆(g)
Before:	5.00×10^{-3} mol	4.07×10^{-2} mol	0
Change:	-5.00×10^{-3} mol	$+3(5.00 \times 10^{-3}$ mol)	$+ 5.00 \times 10^{-3}$ mol
After:	0 mol	2.57×10^{-2} mol	5.00×10^{-3} mol

Total moles after reaction is moles of $XeF_6(g)$ product plus moles of unreacted $F_2(g) = 2.57 \times 10^{-2}$ mol $+ 5.00 \times 10^{-3}$ mol $= 3.07 \times 10^{-2}$ mol

$$PV = nRT; \quad P = \frac{nRT}{V} \qquad P = \frac{(3.07 \times 10^{-2}\text{ mol})(0.083145\text{ L bar K}^{-1}\text{ mol}^{-1})(298.15)}{0.1000\text{ L}}$$

$= 7.61$ bar

4. Which one of the following statements about gases is **FALSE**?

A) The ratio of the partial pressure of gas A to the total pressure is equal to the ratio of the number of moles of gas A to the total number of moles.
B) The volume and temperature of a gas are directly proportional.
C) The total pressure in a vessel is the sum of the partial pressures of all gases in the vessel.
D) The volume and pressure of a gas are directly proportional.
E) The volume and number of moles of a gas are directly proportional.

A) χ_A = mol of A/total mol of gas; $P_A = \chi_A \cdot P_{Tot}$; $P_A/P_{Tot} = \chi_A$ = mol of A/total mol of gas
B) Charles' Law (Think about the balloon with liquid N_2.)
C) Law of Partial Pressures
D) Boyle's Law (Think of a balloon floating higher into the air and popping.)
E) Avogadro's Law (Think of blowing up a balloon.)

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5. A CHEM 1A03 student was given a sample of ice and asked to verify that it came from an ice core. The student melted the ice and weighed a 1.000000 mL sample of the water and then weighted the same volume of pure water on a precise analytical balance at exactly the same temperature. Assuming neither sample contained impurities, what was **the student expecting to observe for the sample compared to the pure water**?

   A) The mass of the sample is *more* than for pure water because ice cores have *less* ^{18}O and *more* ^{16}O.
   B) The mass of the sample is *less* than for pure water because ice cores have *more* ^{18}O and *less* ^{16}O.
   C) The mass of the sample is *exactly* the same as pure water because ice cores have the same composition as pure water.
   D) The mass of the sample is *less* than for pure water because ice cores have *less* ^{18}O and *more* ^{16}O.
   E) The mass of the sample is *more* than for pure water because ice cores have *more* ^{18}O and *less* ^{16}O.

Water containing greater concentrations of ^{16}O evaporates more easily at the equator and precipitates much of the ^{18}O water on its way to the poles. This results in less ^{18}O water at the poles in ice cores and greater ^{16}O content. This would in turn make the ice core samples *less* dense than normal ice. Therefore, an equivalent volume of ice core water would weigh less than a sample of pure water.

6. The antidepressant sertraline can be prepared in six steps with yields of 80.%, 80.%, 50.%, 100.%, 48% and 30.%, respectively. If you started with 1.0 mol of starting material prior to the first step and each step had a 1:1 stoichiometry of reactant to product, **how** many moles of sertraline would you produce?

   A) 0.075
   B) 0.012
   C) 1.0
   D) 0.30
   E) 0.046

$1.0 \text{ mol} \times 0.80 \times 0.80 \times 0.50 \times 1.00 \times 0.48 \times 0.30 = 0.04\underline{6}08$

The yield will equal the moles at each step multiplied by the yield at each step if the step has a 1:1 stoichiometry of reactant to product.

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7. Analysis of an ionic compound yields 2.82 g of Na, 4.35 g of Cl and 7.83 g of O. What is the **empirical formula**?

A) Na_2ClO_2
B) $NaClO$
C) $NaClO_4$
D) $NaClO_2$
E) $NaClO_3$

$n_{Na} = \frac{mass_{Na}}{MM_{Na}} = \frac{2.82\ g}{22.990\ g\ mol^{-1}} = 0.122662\ mol$

$n_{Cl} = \frac{mass_{Cl}}{MM_{Cl}} = \frac{4.35\ g}{35.453\ g\ mol^{-1}} = 0.12260\ mol$

$n_{O} = \frac{mass_{O}}{MM_{O}} = \frac{7.83\ g}{15.999\ g\ mol^{-1}} = 0.4894\ mol$

Divide by lowest number

$Na_{\frac{0.122662}{0.12260}}$ $Cl_{\frac{0.12260}{0.12260}}$ $O_{\frac{0.4894}{0.12260}}$

$= Na_1Cl_1O_4 = NaClO_4$

8. The photoelectric effect is observed for a certain metal using light of wavelength 490. nm or smaller. **How much energy, in J**, is required to eject an electron from the surface of this metal?

A) 4.23×10^{-18}
B) 4.05×10^{-19}
C) 9.83×10^{-19}
D) 3.56×10^{-7}
E) 7.17×10^{-3}

$E = hc/\lambda$
$= (6.6256 \times 10^{-34})(2.9979 \times 10^{8})/(490. \times 10^{-9})$
$= 4.05 \times 10^{-19}\ J$

9. Identify the **FALSE** statement from among the following:

    A) The colour of a sodium street lamp is due to electronic transitions in sodium.
    B) A photon with an energy of 1.988×10^{-15} J has a wavelength shorter than 1 nm.
    C) A 3s orbital has a higher energy than a 2s orbital.
    D) Absorption and emission processes of specific elements are useful for quantifying heavy metal contamination.
    E) An electron with a velocity of 7.274×10^{5} m s^{-1} has a wavelength longer than 10 nm.

A) True. See slide 9 of Unit 3 Day 1 notes and bowls of flame demo.
B) True. $E = hc/\lambda$; 1.988×10^{-15} J $= (6.6256 \times 10^{-34})(2.9979 \times 10^{8})/\lambda$ $\lambda = 1.00 \times 10^{-10}$ m $= 0.1$ nm
C) True. All orbitals of $n = 3$ are higher energy than those of $n = 2$.
D) True. See slides and podcast related to cadmium rice in Unit 3.
E) False. Because an electron is a particle $\lambda = h/mu = \dfrac{(6.6256 \times 10^{-34})}{(9.109 \times 10^{-31}\text{ kg})(7.274 \times 10^{5}\text{ m s}^{-1})}$

$= 1.00 \times 10^{-9} = 1.00$ nm

10. Calculate the **wavelength of light, in nanometers**, emitted when an electron in a hydrogen atom makes a transition from the $n = 4$ to the $n = 2$ state.

    A) 559
    B) 1080
    C) 764
    D) 869
    E) 486

$E_{photon} = R_H[1/(n_i)^2 - 1/(n_f)^2]$ for the transition from $4 \rightarrow 2$.

$2.179 \times 10^{-18}[1/(4)^2 - 1/(2)^2] = -4.08_{5625} \times 10^{-19}$ J

Because the photon was emitted the energy must be negative, however, when calculating the energy of a photon we use the absolute value

$E_{photon} = 4.08_{5625} \times 10^{-19}$ J

$E_{photon} = hc/\lambda$; or $\lambda = hc/E_{photon} = (6.6256 \times 10^{-34})(2.9979 \times 10^{8}\text{ m s}^{-1})/(4.08_{5625} \times 10^{-19}\text{ J})$
$= 4.86 \times 10^{-7}$ m $= 486$ nm

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11. Which of the following statements are **FALSE**?

(i) Blue photons have a higher frequency than red photons.
(ii)A solar cell made of a single element can absorb photons of all frequencies of the solar spectrum.
(iii) Light is emitted when an excited electron relaxes to a lower energy level.
(iv) As the quantum number *n* of an orbital increases, the average distance between nucleus and electrons increases.
(v) The set of quantum numbers ($n = 3$, $l = 2$, $m_l = -1$, $m_s = -½$) could describe an electron in a phosphorus atom in its ground state.

A) i, ii
B) iii, iv
C) i, iv
D) iii, v
E) ii, v

i) True. See electromagnetic spectrum.
ii) False. A single element will absorb discrete wavelenths only because it is quantized.
iii) True. This is the basis of an emission spectrum.
iv) True. *n* is the principle quantum number and refers to the shells and their distance from the nucleus.
v) False. $n = 3$, $l = 2$ refers to a 3d electron. The highest energy orbitals for Phophorous in the ground state is 3p or $n = 3$, $l = 1$.

12. Which electron configuration corresponds to an **excited state** of a **non-metallic** atom?

A) [Ne] $3s^2 3p^3 4s^1$ Excited State S
B) [Ar] $4s^2 3d^5$ Ground State Mn
C) [Ar] $4s^1 4p^1$ Excited State Ca
D) [Ne] $3s^2 4p^1$ Excited State Al
E) [Ar] $4s^2 3d^{10} 4p^5$ Ground State Br

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13. According to the Bohr model of the H atom, the **difference of energy between the levels n =1 and n = ∞** corresponds to which of the following?

A) The energy of the longest-wavelength photon absorbed by hydrogen in its ground state.
B) The electronegativity of hydrogen.
C) The energy of the shortest-wavelength photon absorbed by hydrogen in an excited state.
D) The electron affinity of hydrogen.
E) The ionization energy of hydrogen.

A) That would correspond to n = 1 to n = 2.
B) Electronegativity is a measure of electron attraction between bonded atoms.
C) That would correspond to n = 2 to n = ∞. n = 1 is a ground state electron.
D) Electron affinity for hydrogen would be a relaxing, not exciting process, and would involve 2 electrons which goes beyond the limits of the Rydberg equation.
E) True.

14. The O–H bond energy in water is approximately 467 kJ mol^{-1}. The photon with just enough energy to break one O–H bond has a **frequency (in Hz)** of

A) 4.67×10^{12}
B) 4.31×10^{15}
C) 9.45×10^{14}
D) 1.17×10^{15}
E) 2.37×10^{18}

Energy to break 1 bond = $467000\ J / N_A = 467000\ J / (6.022 \times 10^{23})$

$= 7.75_{4898705} \times 10^{-19}$ J

$E = h\nu$; $7.75_{4898705} \times 10^{-19}\ J = (6.6256 \times 10^{-34}\ J)\nu$

$\nu = 1.17 \times 10^{15}$ Hz

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15. Determine the **<u>FALSE</u>** statement regarding the <u>general</u> trends of the periodic table.

    A) an element X will have a larger radius than X^+
    B) the element with the smallest first ionization energy in a row will have the largest atomic radius of that row
    C) an element X will have a smaller radius than X^-
    D) the second ionization energy for Na will be larger than the first ionization energy of Ne
    E) Z_{eff} increases down a group

A) True. A cation of an element has the same charge in the nucleus but fewer electrons to repel one another and therefore has a smaller radius.
B) True. The element with the smallest first ionization energy is always the alkali metal in group 1 which also has the largest radius as radius decreases from left to right across a period.
C) True. An anion of an element has the same charge in the nucleus but more electrons that repel one another and therefore has a larger radius.
D) True. Both would be isolectronic but Na would have more protons in the nucleus and therefore have a stronger hold on its remaining electrons/
E) False. Z_{eff} remains essentially constant going down a group.

16. Which **one** of the following rankings is **FALSE** ordered with respect to the relative atomic/ionic size?

    A) P > N radius increases down a group
    B) $K^+ > Ca^{2+}$ isoelectronic ions but K^+ has fewer protons to pull on the electrons
    C) $F^- > F$ radius increases when forming an anion
    D) Mg > Na radius decreases across a period from left to right
    E) Na > F Na has an extra shell compared to F

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17. Which of the following atom/ions would require the **most energy** to remove one electron?

A) Li
B) Ca^{2+} the electron is removed from an inner shell requiring the most energy
C) Si^{2+}
D) Al^{2+}
E) P^{2+}

18. How **MANY** of the following would produce a **basic** solution when dissolved in or reacted with water?

CO_2, Na_2O, MgO, Na, SO_3

A) 3
B) 5
C) 2
D) 1
E) 4

$2Na + 2H_2O \rightarrow 2NaOH + H_2$
Metal oxides form basic solutions: Na_2O, MgO
Non-metal oxides form acidic solutions: CO_2, SO_3

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19. Identify the **FALSE** statement regarding **electronegativity**.

A) Fluorine is the most electronegative atom.
B) The electronegativity of chlorine is greater than that of calcium.
C) Electronegativity increases up and to the right on the periodic table.
D) Electronegativity is the energy associated with an atom in the gas phase accepting an electron.
E) Polar bonds exist when there is a significant difference in electronegativity of the bonded atoms.

ELECTRON AFFINITY is the energy associated with an atom in the gas phase accepting an electron.

20. Which **one** of the following elements would have the **least metallic character**?

A) As Metal or near-metalloid
B) Ga Metal
C) S Non-Metal
D) Be Metal
E) Cr Metal

Non-metallic character increases going up and from left to right in the periodic table.

Extra space for rough work

Extra space for rough work

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- **Some general data are provided on this page.**
- **A Periodic Table with atomic weights is provided on the next page.**

STP = 273.15 K, 1 atm

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

$h = 6.6256 \times 10^{-34}$ Js

density(H_2O, l) = 1.00g/mL

Specific heat of water = 4.184 J / g·°C

$R = 8.3145$ J K^{-1} mol^{-1} = 0.08206 L atm K^{-1} mol^{-1} = 0.083145 L bar K^{-1} mol^{-1}

F = 96485 C/mol

$c = 2.9979 \times 10^8$ m/s

$m_e = 9.109 \times 10^{-31}$ kg

$\Delta H^o_{vap}[H_2O] = 44.0$ kJ mol^{-1}

1 bar = 100.00 kPa = 750.06 mm Hg = 0.98692 atm

1 J = 1 kg m^2 s^{-2} = 1 kPa L = 1 Pa m^3

1 cm^3 = 1 mL

1 Hz = 1 cycle/s

0°C = 273.15 K

1 m = 10^6 µm = 10^9 nm = 10^{10} Å

1 g = 10^3 mg

De Broglie wavelength:

$\lambda = h / mu = h / p$

Hydrogen atom energy levels:

$E_n = -R_H / n^2 = -2.179 \times 10^{-18}$ J / n^2

$KE = ½mu^2$

Nernst Equation:

$$E = E° - \frac{RT}{zF}\ln Q \quad = E° - \frac{0.0257\text{ V}}{z}\ln Q \quad = E° - \frac{0.0592\text{ V}}{z}\log_{10} Q$$

Entropy change: $\Delta S = \dfrac{q_{rev}}{T}$

Solubility Guidelines for Common Ionic Solids
Follow the lower-numbered guideline when two guidelines are in conflict. This leads to the correct prediction in most cases.

1. Salts of group 1 cations and the NH_4^+ cation are soluble . Except LiF and Li_2CO_3 which are insoluble.
2. Nitrates, acetates, bicarbonates, and perchlorates are soluble.
3. Salts of silver, lead and mercury (I) are insoluble. Except AgF which is soluble.
4. Fluorides, chlorides, bromides, and iodides are soluble. Except Group 2 fluorides which are insoluble
5. Carbonates, phosphates, chromates, sulfides, oxides, and hydroxides are insoluble. Except Group 2 sulfides and hydroxides of Ca^{2+}, Sr^{2+}, and Ba^{2+} which are soluble.).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

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PERIODIC TABLE OF THE ELEMENTS

I 1	II 2	3	4	5	6	7	8	9	10	11	12	III 13	IV 14	V 15	VI 16	VII 17	VIII 18
1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 105.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	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 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	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 Unq [261]	105 Unp [262]	106 Unh [263]												

Transition Metals: groups 3–12

Atomic weights are based on $^{12}C = 12$ and conform to the 1987 IUPAC report values rounded to 5 significant digits. Numbers in [ ] indicate the most stable isotope.

* Lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
** Actinides	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 [262]

END OF EXAM