Name: _____ Student number: _____

Chemistry 1A03 **Test 1** **Sep 30, 2016**

McMaster University **VERSION 1 - SOLUTIONS** **17:30 –19:00**

Instructors: L. Chen, L. Davis, D. Emslie, A. Hitchcock

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. They must NOT be transferred between students. Use of any aids other than those provided, is not allowed.

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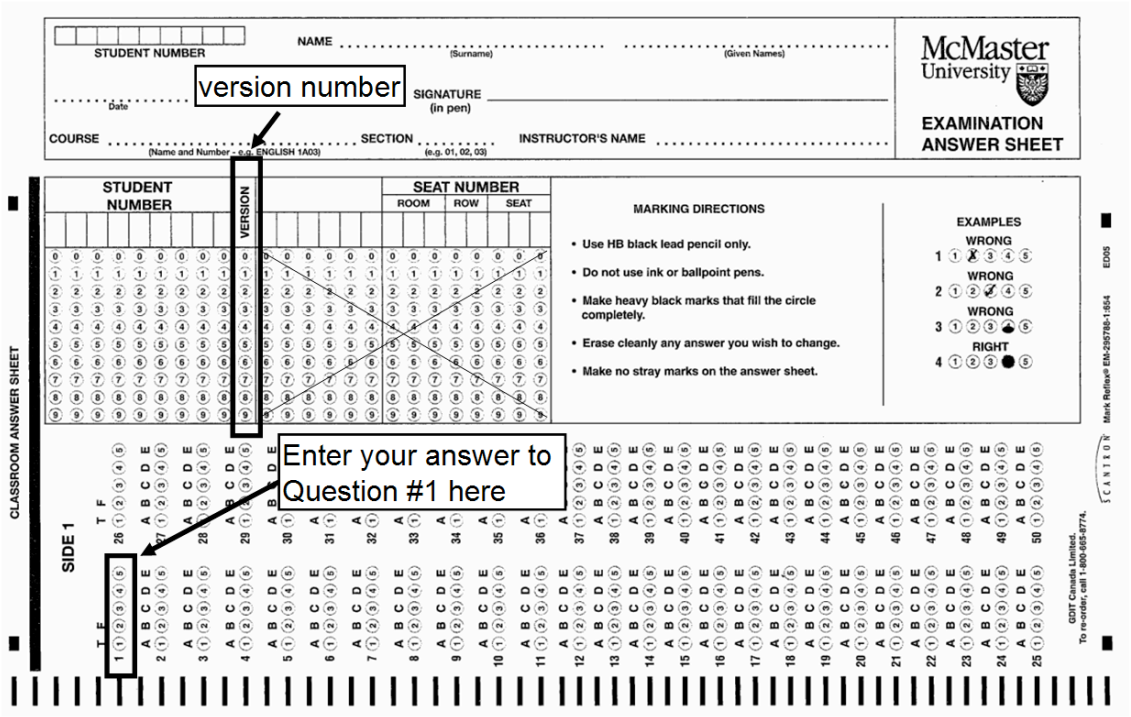
OMR EXAMINATION – STUDENT INSTRUCTIONS

NOTE: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED: YOUR 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. **ONLY USE THE RED SIDE OF THE OMR FORM.**
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 mass** of carbon?

A) 58.93
B) 6
C) 16
D) 6.94
E) 12.01

Look it up in the period table at the back.
Do not confuse atomic mass and atomic number.

2. The nucleus of which **one** species contains the greatest number of **protons**?

A) F^-
B) P^-
C) Cl^-
D) S^{2+}
E) Si^-

Largest Z will have the most number of protons in the nucleus

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3. A sample of titanium dioxide (TiO_2) with a mass of 2.024 g is heated in excess H_2 gas to produce water vapour and 1.889 g of *another* titanium oxide. What is the **empirical formula** of the titanium oxide produced? The unbalanced equation for this reaction is:

$$TiO_2\ (s) + H_2\ (g) \rightarrow Ti_xO_y\ (s) + H_2O\ (g) \quad \textit{(unbalanced)}$$

y/x		
3	A)	TiO_3
0.5	B)	Ti_2O
1.67	**C)**	**Ti_3O_5**
1	D)	TiO
0.67	E)	Ti_2O_3

$M(TiO_2$= 47.87+2*15.99)=79.88 g/mol; 2.024g is (2.024g /79.88 g/mol) = 0.0253 mol

What we want is the ratio z = y/x

If 1:1 stoichiometry of TiO_2 and Ti_xO_y then product is 0.253 mol which weights 1.889 g
Thus (in this assumption) $M(Ti_xO_y)$ = (1.889 g/0.253 mol) = 74.664 g

Since M(Ti) is 47.87) there is 74.66 - 47.87 = 26.78 g of O ➔ (26.78/15.99) = **1.67**
So RATIO (y/x) = 1.67 which matches the (y/x) value for **Ti_3O_5**

BALANCED RXN: $3\ TiO_2\ (s) + H_2\ (g) \rightarrow Ti_3O_5\ (s) + H_2O\ (g)$

NB there are other ways to solve this problem !!

4. Identify the **FALSE** statement among the following statements.

A) A group and a period will intersect at a right angle.
B) If pieces of two different metals have equal volume, the metal with the highest density will have the lowest mass.
C) The atomic number of an element is always smaller than the average atomic mass of the natural abundance of that element.
D) The oxidation number of P in PO_4^{3-} is +5.
E) Concentration is an intensive property.

A TRUE	group up/down; period left/right
B FALSE	**density is mass/volume; if volume is the same the denser material will have the highest mass**
C TRUE	all elements except the hydrogen atom with no neutrons the atomic mass is higher than the atomic number by the number of neutrons. The only exception would be ^1H if it was isotopically pure (expensive) in which case the atomic mass and number would be the same
D TRUE	O has O.N. of -2; 4 * (-2) = 8, of which 3 are used for the charge; P is +5
E TRUE	

5. How many **grams** of calcium oxide, CaO, can be produced from 4.20 g of calcium metal and 1.60 g of oxygen gas?

A) 5.26
B) 2.80
C) 5.61
D) 6.80
E) 2.94

M(Ca) = 40.08 g/mol ➔ 4.20 g Ca metal is n_{Ca} = (4.20g/40.08 $g.mol^{-1}$) = 0.105 mol
M(O_2) = 2*15.99 = 31.98 g/mol ➔ 1.60 g O_2 is n_{O2}=(1.60 g/ 31.98 g/mol) = 0.05 mol

BALANCED RXN: 2 Ca + O_2 → 2CaO

Since 2 moles of Ca react with 1 mol O_2 , 0.100 mol Ca will react with 0.05 mol O_2. since there is more than 0.100 mol Ca, the limiting reagent is O_2 ➔ 2* 0.05 = 0.10 mol of CaO will be produced

M(CaO) = 40.08 + 15.99) = 56.08 ➔ mass of CaO will be 0.10*56.08 = **5.61 g**

6. What is the **oxidation state** of boron in B_2O_3 ?

A) −2
B) −1 (was -2 in original version of test)
C) +1
D) −3
E) +3

O.N. (O) = -2, so 3 O^{2-} ➔ 6- charge, must be balanced by 6+ on 2 boron atoms, or **O.N (B)= +0.3**

7. Which **one** of the following is **NOT** an allowable set of quantum numbers?

A)	n = 3	l = 2	$m_l = -2$	$m_s = 1/2$
B)	n = 1	l = 0	$m_l = 0$	$m_s = -1/2$
C)	n = 2	l = 0	$m_l = 0$	$m_s = 1/2$
D)	n = 2	l = 1	$m_l = -1$	$m_s = 1/2$
E)	**n = 3**	**l = 3**	**$m_l = -1$**	$m_s = 1/2$

The maximum value of l is n-1.

8. Which of the following statements regarding the transition of an electron from **n = 5 to n = 3** in a hydrogen atom are **FALSE**?

T i) The wavelength of light emitted from this transition is 1282 nm.
F ii) The wavelength of light emitted for this transition is shorter than the wavelength emitted for the transition from n = 4 to n = 2.
F iii) The electron has relaxed to the ground state.
T iv) The atom has not been ionized during this transition.
T v) The value of ΔE for this transition is negative.

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

$$\Delta E = E(n=5) - E(n=3) = \frac{R_H}{5^2} - \frac{R_H}{3^2} = \frac{-2.179x10^{-19}}{25} - \frac{-2.179x10^{-19}}{9}$$

i) $$= (-8.716x10^{-20}) - (-2.421x10^{-20}) = 1.55x10^{19}\,J$$

$$\lambda = \frac{hc}{\Delta E} = \frac{6.626x10^{-34}\,J.s)(2.99x10^{8}\,m/s)}{1.55x10^{19}\,J} = 1.282x10^{-6}\,m = 1282nm$$

9. The following electron configuration would represent a singly charged **anion** of which **one** of the following elements?

$$1s^2 2s^2 2p^6 3s^2 3p^6$$

A) Argon
B) Sodium
C) Potassium
D) Calcium
E) Chlorine

The corresponding neutral will be $1s^2 2s^2 2p^6 3s^2 3p^5$
which is the electron configuration of **Cl.**

10. Which **one** of the following statements is **FALSE**?

A) An electronic transition from n = 1 to n = 2 is higher energy than a transition from n = 2 to n = 3.
B) The wavelength of blue light is shorter than that of green light.
C) Atomic absorption spectra can be used to identify the presence of elements in a given sample.
D) Absorption and emission processes involving transitions between the same pair of energy levels do not have the same energy.
E) Atomic absorption spectra can be used to quantify the amount of an element in a given sample.

A TRUE - levels get closer together as n increases
B TRUE
C TRUE
D FALSE Absorption and emission processes involving transitions between the SAME pair of energy levels will absorb or emit photons with the same energy, since transitions between the SAME pair of energy levels have the same magnitude of energy.
E TRUE

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11. How many **electrons** in an atom can be described by the following set of quantum numbers?

$n = 3$ $\quad l = 2$ $\quad m_l = 1$

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

There are 4 quantum numbers. Once the n, l and m_l are established the only possibilities are $m_s = +1/2$ and $m_s = -1/2$

12. The photoelectric effect is observed for a certain metal that has a threshold energy of 4.12×10^{-19} J. What is the **wavelength of the incident light in nanometers**, if the electrons ejected from the surface of this metal have a velocity of 7.26×10^5 m s^{-1} ?

A) 423
B) 375
C) 402
D) 211
E) 305

$$E_{kinetic} = \frac{1}{2}mv^2 = \frac{1}{2}(9.109x10^{-31}kg)(7.26x10^5 m.s^{-1})^2 = 2.398x10^{-19}J$$

$$E_{photon} = E_{kinetic} + E_{threshold} = 2.398x10^{-19}J + 4.12x10^{-19,J}) = 6.52x10^{-19}J$$

$$\lambda = \frac{hc}{E} = \frac{(6.6256x10^{-24}J.s)(2.99x10^{-8}m.s^{-1})}{6.52x10^{-19}J} = 3.048x10^{-6}m = 304.8nm$$

13. Which of the following statements regarding the photoelectric effect are **FALSE**?

T (i) The number of photoelectrons generated depends on the intensity of the incident light.
F (ii) Photoelectrons are generated when the frequency of the incident light is lower than the threshold frequency.
T (iii) Photoelectrons can be generated when light strikes a metal surface to which a voltage is applied.
F (iv) The kinetic energy of the emitted electrons depends on the intensity of the incident light.
T (v) The threshold energy of the metal must be lower than the energy of the incident light to eject an electron.

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

14. The **effective nuclear charge (Z_{eff})** felt by the outermost electrons is the **strongest** for which of the following elements?

A) F
B) N
C) Be
D) B
E) O

Effective nuclear charge increases from left to right across a period.
F is the rightmost element of this set of period 2 elements.

15. Which **one** of the following statements is **FALSE**?

T A) The first ionization energy of N is greater than that of O.
T B) The first ionization energy of B is smaller than that of Be.
F C) The effective nuclear charge, Z_{eff}, felt by the valence electrons of Al is greater than that of S.
T D) The electron affinity of F is more negative than that of O. (note: the electron affinity of O is -141 $kJ.mol^{-1}$).
T E) When dissolved in water, MgO is basic.

A) N is more stable than O due ½ filled 2p shell ➔ N has higher IE than O
B) Be is more stable than B due to filled 2s shell ➔ Be has larger IE than B.
C) Zeff increases across a period, while Al comes earlier than S in the 3rd period
D) F has the most negative EA of all elements
E) Metal oxides make basic solutions. $MgO + H_2O = Mg^{2+}(aq) + 2\ OH^-$

16. Which **one** of the following species is in the *middle* position when the following five atoms and ions are ranked according to increasing **size**?

N, P, Cs, Mg^{2+}, Cl^-

A) Mg^{2+}
B) Cl^-
C) N
D) P
E) Cs

Order is $Mg^{2+} \leq N < P < Cl^- < Cs$

Among the 3 neutrals, N is the smallest, P is larger, and Cs is much larger.

Mg^{2+} is a 3rd row element with a 2+ charge, and a [Ne] electronic configuration. It would be expected to be at least as small as nitrogen. Therefore Mg^{2+} and N are the smallest.

Cl^- is a 3rd row element with a 1– charge, and an [Ar] electronic configuration. it would be expected to be significantly larger than P since they are close together in the same row of the periodic table. However, Cl^- it is not as large as a Cs atom, which is in group 6 and is located on the far left of the periodic table (where the largest atomic radii are observed). Regardless of their relative size, Cl^- and Cs are the largest atoms/ions in the list, so P is in the middle.

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17. How **many** of the following species will **react** when placed in a solution of HNO_3 (aq)?

Na_2O, CaO, Al_2O_3, SiO_2, **Cl_2O_7**

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

Note – all students were awarded 2/2 for this question as we recognize that it may have caused some confusion.

Na_2O and CaO will react with H_2O to form NaOH and $Ca(OH)_2$ [note: bases react with acids, so these will react further to form $NaNO_3$ + H_2O, and $Ca(NO_3)_2$ + 2 H_2O, respectively, although this subsequent reactivity is not required to answer the question].

Cl_2O_7 is an "acidic oxide", so it will react with H_2O to form strongly acidic $HClO_4$.

Al_2O_3 is alumina, also known as corundum (both ruby and sapphire are types of corundum), so it will not react with dilute nitric acid.

SiO_2 is quartz (the major component of sand), so it will not react with dilute nitric acid.

Therefore, **3** of the above species will react when placed in HNO_3 (aq).

Note: It is possible that people may not have realized that Al_2O_3 and SiO_2 will be unreactive towards aqueous nitric acid, and may have interpreted this question as asking which of the five compounds are "basic oxides" which could potentially react with an acid to generate a salt; in this case, Na_2O, CaO and Al_2O_3 are candidates (although the latter is amphoteric and unreactive towards dilute nitric acid), and again the answer is 3. Alternatively, this question may just have caused confusion!, so all answers (or no answer) will be worth 2 marks.

18. Which **one** of the following reactions represents the **third ionization energy** of vanadium?

A) $V^{2-}(g) + e^- \rightarrow V^{3-}(g)$
B) $V^{3+}(g) \rightarrow V^{4+}(g) + e^-$
C) $V^{3+}(g) + e^- \rightarrow V^{2+}(g)$
D) $V(g) \rightarrow V^{3+}(g) + 3e^-$
E) $V^{2+}(g) \rightarrow V^{3+}(g) + e^-$

The third ionization energy corresponds to the indicated transition.

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19. Which **one** of the following relationships regarding ionic and/or atomic **size** is **TRUE**?

F	A)	$Na < Na^+$
T	**B)**	**$Cl < Cl^-$**
F	C)	$Al < Al^{3+}$
F	D)	$S^{2-} < O^{2-}$
F	E)	$Ne^{2+} < Ne^{3+}$

Cations are smaller than neutrals of the same element (A, C)
Anions are larger than the neutral species of the same element (B)
Higher charged cations are smaller than lower charged cations (E)
Higher charged anions are larger than lower charged anions
For the same charge state, size increases from left to right across a period (D)

20. Which **one** of the following species is **diamagnetic**?

A) Cr^{2+}
B) Sr^+
C) I^-
D) Co^{3+}
E) Br

A diamagnetic species has no unpaired electrons

Cr^{2+} [Ar] $4s^2 3d^1$ - 1 unpaired electron (actually it will be $4s^0 3d^3$ but still unpaired)

Sr^+ [Kr] $4s^1$ 1 unpaired electron

I^- [Kr] $4s^2 3d^{1-} 4p^6$ - NO unpaired electrons

Co^{3+} [Ar] $4s^2 3d^4$ - 1 unpaired electron (actually it will be $4s^0 3d^6$ but still unpaired)

Br [Ar] $4s^2 3d^{1-} 4p^5$ 1 unpaired electron

Extra space for rough work

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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

$F =$ 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}

$R = 8.3145$ J K^{-1} mol^{-1} = 0.08206 L atm K^{-1} mol^{-1} = 0.083145 L bar K^{-1} 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: $\Delta S = \frac{q_{rev}}{T}$

Aqueous Solubiity: 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

ALDRICH®

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