Name: _____ **Student number: _____**

Chemistry 1E03 **Test 2** **Nov. 15, 2013**

McMaster University ***VERSION 1***

Instructors: Drs. R.S. Dumont & A.P. Hitchcock

Duration: 120 minutes

This test contains 20 numbered pages printed on both sides. There are **30** multiple-choice questions appearing on pages numbered 3 to 16. Pages 17 and 18 provide extra space for rough work. Page 19 includes some useful data and equations, and there is a periodic table on page 20. You may tear off the last pages 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 60. There is **no** additional penalty for incorrect answers.

BE SURE TO ENTER THE CORRECT VERSION NUMBER 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 periodic tables or any aids, other than those provided, is not allowed.

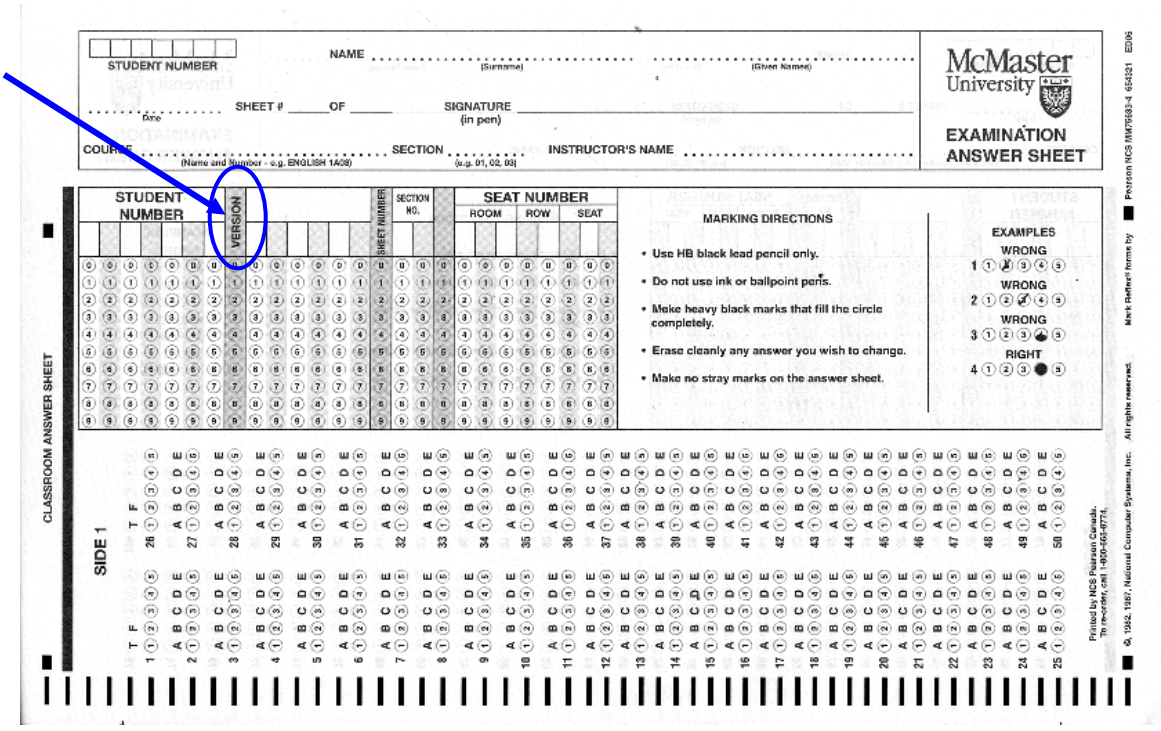
Name: _____ Student number: _____

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, **exam version number** in the space provided and <u>fill in the corresponding bubble numbers underneath</u>.
3. 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.
4. Pay particular attention to the Marking+ Directions on the form.
5. Begin answering the question using the first set of bubbles, marked “1”.



1. Balance the following redox reaction in **basic** solution.

$$Cr(OH)_3(s) + ClO^-(aq) + OH^-(aq) \rightarrow CrO_4^{2-}(aq) + Cl^-(aq) + H_2O(l)$$

When this has been done correctly, the stoichiometric **coefficients** for $Cr(OH)_3(s)$, $ClO^-(aq)$ and $OH^-(aq)$, in order from **left** to **right** are:

.

A) 2, 3, 4
B) 2, 4, 6
C) 1, 2, 3
D) 3, 4, 5
E) 1, 1, 4

2. One of the most potent carcinogens (found in air particulate, cigarette smoke and grilled food) is benzo[*a*]pyrene (molar mass = 252.30 g/mol). Combustion analysis finds that it is 95.21 mass % C and 4.79 mass % H. Which is the **correct molecular formula**?

.

A) $C_{20}H_{14}$
B) $C_{19}H_{18}$
C) $C_{18}H_{12}$
D) $C_{20}H_{12}$
E) $C_{22}H_{16}$

3. In an ice calorimeter, 0.3233 g of Fe are oxidized to Fe^{2+} in an exothermic reaction. As a result, 3.87 g of ice melts, producing water. Calculate how much **heat** (in kJ **per mole of Fe**) is produced. The enthalpy of fusion of ice is 6.012 $kJ.mol^{-1}$.

   A) 3.99
   B) 223
   C) 108
   D) 1.29
   E) 70.8

4. Formic acid, HCOOH, is the monoprotic acid that causes the sting in ant bites. A 0.2361 g sample containing formic acid and an unreactive substance was titrated to the end point by 28.25 mL of a 0.1126 M NaOH solution. What was the **percent purity** (percent **by mass)** of formic acid in the sample?

   A) 41.53 %
   B) 54.80 %
   C) 18.35 %
   D) 62.01 %
   E) 6.043 %

5. Calculate the standard enthalpy of formation of **liquid benzene**, C_6H_6, in kJ mol^{-1}, from its standard enthalpy of combustion which is –3268 kJ mol^{-1}. Data:

$\Delta H_f°(H_2O, l)$ = –285.8 kJ mol^{-1} $\Delta H_f°(CO_2, g)$ = –393.5 kJ mol^{-1}
$\Delta H_f°(C, diamond)$ = 1.90 kJ mol^{-1} $\Delta H_f°(CO, g)$ = –110.5 kJ mol^{-1}

A) –48
B) –52
C) 52
D) 50
E) –50

6. If a reaction will occur, identify the correct **net ionic equation** for the reaction of calcium chloride with potassium phosphate, in water:

A) No net reaction occurs
B) $3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s)$
C) $CaCl_2(aq) + K_3PO_4(aq) \rightarrow Ca_3(PO_4)_2(aq) + KCl(aq)$
D) $Ca^{2+}(aq) + K_2PO_4(aq) \rightarrow Ca_3(PO_4)_2(s) + 2K^+(aq)$
E) $K^+(aq) + Cl^-(aq) \rightarrow KCl(s)$

7. Which **one** of the following reactions is an oxidation-reduction reaction?

A) $KCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + KNO_3(aq)$
B) $SrCO_3(s) \rightarrow SrO(s) + CO_2(g)$
C) $NaOCl(aq) + CO(g) \rightarrow NaCl(aq) + CO_2(g)$
D) $NaNH_2(s) + 2\ HBr(aq) \rightarrow NaBr(aq) + NH_4Br(aq)$
E) $SiCl_4(l) + 2\ H_2O(l) \rightarrow 4\ HCl(aq) + SiO_2(s)$

8. Which atom has the **greatest number of *unpaired* electrons** in its ground-state electron configuration?

.

A) Pb
B) Ga
C) N
D) Be
E) S

9. Put the following ions in order of **increasing ionic radius** (i.e., increasing size): Ca^{2+}, Cl^{-}, K^{+}, S^{2-}.

.

A) $Ca^{2+} < K^{+} < Cl^{-} < S^{2-}$
B) $S^{2-} < Cl^{-} < K^{+} < Ca^{2+}$
C) $K^{+} < Ca^{2+} < S^{2-} < Cl^{-}$
D) $Cl^{-} < S^{2-} < Ca^{2+} < K^{+}$
E) $Ca^{2+} < Cl^{-} < K^{+} < S^{2-}$

10. Which **one** of the following is **not** a valid set of quantum numbers, (n, ℓ, m_ℓ), for an orbital of the hydrogen atom?

.

A) 2, 0, 0
B) 1, 0, 0
C) 3, 2, –1
D) 2, 1, 0
E) 2, 2, 1

11. Calculate the **longest wavelength (in μm)** of light **emitted** by an excited hydrogen atom in which the electron occupies the energy level n = 6. Note that 1 μm = 10^{-6} m.

.

A) 3.28
B) 93.7
C) 2.28
D) 1.00
E) 7.46

12. Determine the **standard enthalpy of formation (in kJ mol^{-1})** of solid calcium chloride from the following data (all in kJ mol^{-1}):

ΔH_f^o[Ca(g)] = 178
First ionization energy of Ca(g) = 590
Second ionization energy of Ca(g) = 1150
ΔH_f^o[Cl(g)] = 122
Electron affinity of Cl(g) = –349
Lattice enthalpy of $CaCl_2$(s) = –2260

.

A) –2126
B) –1418
C) –1906
D) +610
E) –796

13. Identify the correct order of **decreasing** molecular dipole moment among the following.

.

A) $CO_2 > H_2O > H_2S$
B) $H_2O > CO_2 > H_2S$
C) $H_2S > H_2O > CO_2$
D) $H_2S > CO_2 > H_2O$
E) $H_2O > H_2S > CO_2$

14. Estimate the **enthalpy change** (in kJ per mole of **methanol** produced) of the following gas-phase reaction. (Hint: write the Lewis structures of the molecules before using the given bond enthalpies.)

$$HCOOH(g) + 2\ H_2(g) \rightarrow CH_3OH(g) + H_2O(g)$$

i.e., methanoic acid + hydrogen $\rightarrow$ methanol + water

Bond enthalpies (kJ mol^{-1}): C-C 347; C-O 360; C=O 736; C-H 413; O-H 464; H-H 436

.

A) –172
B) –146
C) +172
D) +83
E) –83

15. What is the **shape** of the methanoate anion, HCO_2^- (carbon is the central atom, and both oxygen atoms are terminal)?

.

A) T-shaped
B) trigonal planar
C) linear
D) tetrahedral
E) trigonal pyramidal

16. At 125°C, K_P = 0.25 for the decomposition of sodium hydrogen carbonate,

$$2\ NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g).$$

If 10.0 g of $NaHCO_3(s)$ are added to a 1.00 L flask which is then heated to 125°C, what is the **partial pressure of CO_2** (in atm) in the flask when the reaction comes to equilibrium?

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A) 0.75
B) 1.25
C) 0.25
D) 1.0
E) 0.50

17. A vessel is filled with $N_2O_4(g)$ to an initial pressure of 3.01 atm. Some of this gas decomposes into $NO_2(g)$. At equilibrium, the partial pressure of $N_2O_4(g)$ is found to be 2.71 atm. What is the value of the **equilibrium constant** for the decomposition of $N_2O_4(g)$ into $NO_2(g)$, at the temperature of this experiment?

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A) 1.73
B) 1.42
C) 3.11
D) 0.133
E) 0.233

18. Pure NOBr(g) is introduced in an evacuated container. It dissociates according to the following equilibrium:

$$2\ NOBr(g) \rightleftharpoons 2\ NO(g) + Br_2(g)$$

When equilibrium is established at 25°C, NOBr is 34% dissociated and the total equilibrium pressure *P* is 0.25 atm. What was the **initial partial pressure** of NOBr (in atm)?

.

A) 0.51
B) 0.073
C) 0.21
D) 0.39
E) 0.068

19. Solid ammonium nitrite is added to an initially evacuated container. It decomposes according to the chemical equilibrium,

$$NH_4NO_2(s) \rightleftharpoons N_2(g) + 2\ H_2O(g).$$

Which of the following statements are **FALSE** regarding this equilibrium?

.

A) Reducing the volume of the container increases the amount of $NH_4NO_2(s)$.
B) Adding more $NH_4NO_2(s)$ to the container does not affect the partial pressure of $N_2(g)$.
C) Removing water (via a desiccant - a material that absorbs water) does not affect the amount of $NH_4NO_2(s)$.
D) The partial pressure of water in the container is twice that of nitrogen.
E) Pumping additional $N_2(g)$ into the container increases the amount of solid ammonium nitrite.

20. Consider the following equilibrium in a container with fixed volume:

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \qquad \Delta H = -198.2\ kJ\ mol^{-1}$$

Which of the following changes will **NOT** increase the amount of $SO_2(g)$?

.

A) An inert gas is added to increase the total pressure.
B) O_2 is removed.
C) The temperature is increased.
D) SO_3 is added.
E) The volume is increased.

21. For the reaction, $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$, the equilibrium constant at 112ºC is $K_P = 0.220$. For a mixture of $CaCO_3(s)$, $CaO(s)$ and 0.50 atm partial pressure $CO_2(g)$, at 112ºC, which **one** of the following statements is **TRUE**?
.
A) Q > K, the reaction will proceed to the right.
B) Q < K, the reaction will proceed to the left.
C) Q < K, the reaction will proceed to the right.
D) Q = K, the system is at equilibrium.
E) Q > K, the reaction will proceed to the left.

22. PCl_5 (41.6 g) is placed in a 1.00 L vessel and decomposed at 300ºC ($K_P = 2.455$) to form PCl_3 and Cl_2. At this temperature, all compounds are in the gas phase. At equilibrium, what is **the partial pressure of PCl_3** (in atm)?
.
A) 2.07
B) 4.13
C) 4.67
D) 3.73
E) 0.593

23. In which of the following processes does the **entropy of the system decrease**?

.

(i) $CH_4\,(g) + 2\,O_2\,(g) \rightarrow CO_2\,(g) + 2\,H_2O\,(l)$
(ii) $B_2O_3\,(s) + 3\,H_2O\,(g) \rightarrow B_2H_6\,(g) + 3\,O_2\,(g)$
(iii) $H_2\,(g) + ½\,O_2\,(g) \rightarrow H_2O\,(l)$
(iv) $I_2\,(s) \rightarrow I_2\,(g)$
(v) $Li^+\,(g) + F^-\,(g) \rightarrow LiF(s)$

.

A) none
B) iii, v
C) all
D) i, iii, v
E) ii, iv

24. When $NH_3(g)$ reacts spontaneously with HCl(g), solid NH_4Cl is formed. Which **one** of the following correctly describes the changes in ΔG, ΔH and ΔS ?

.

A) $\Delta G > 0,\ \Delta H < 0,\ \Delta S < 0$
B) $\Delta G < 0,\ \Delta H > 0,\ \Delta S > 0$
C) $\Delta G > 0,\ \Delta H > 0,\ \Delta S > 0$
D) $\Delta G < 0,\ \Delta H > 0,\ \Delta S < 0$
E) $\Delta G < 0,\ \Delta H < 0,\ \Delta S < 0$

25. The reaction $2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$ is spontaneous **except** at very high temperature. Which of the following statements is/are **TRUE** for this reaction?

(i) $\Delta H < 0$
(ii) $\Delta S < 0$
(iii) H_2 (g), O_2 (g) and H_2O (g), all at 1 atm partial pressure, are in equilibrium at very high temperature.
(iv) $\Delta G < 0$ except at very high temperature.

.

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

26. Given the following data, calculate ΔG^o (in kJ per mole of C_2H_2(g) produced) for the reaction:

$$2C(s) + H_2(g) \rightarrow C_2H_2(g)$$

$C_2H_2(g) + 5/2\ O_2(g) \rightarrow 2\ CO_2(g) + H_2O(l)$ $\quad \Delta G^o = -1234\ kJ\ mol^{-1}$
$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta G^o = -394\ kJ\ mol^{-1}$
$H_2(g) + ½\ O_2(g) \rightarrow H_2O(l)$ $\quad \Delta G^o = -237\ kJ\ mol^{-1}$

.

A) –603
B) +209
C) +366
D) –1865
E) +603

27. Calculate the **boiling point** temperature (**in °C**) of bromine given the following data:

$\Delta H_f^\circ[Br_2(g)] = 30.907$ kJ mol^{-1}
$S^\circ[Br_2(l)] = 152.2$ J K^{-1} mol^{-1}
$S^\circ[Br_2(g)] = 245.463$ J K^{-1} mol^{-1}

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A) 18
B) 276
C) 3
D) 58
E) 126

28. In the process where 1.00 mole of white tin is converted to 1.00 mole of gray tin at 25°C the change in entropy is –7.5 J K^{-1}. Which **one** statement is **TRUE** ?

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A) Gray tin has a higher molar entropy than white tin.
B) Gray tin is more "ordered" than white tin.
C) White tin is more "ordered" than gray tin.
D) From entropy considerations alone the reaction will be spontaneous.
E) Gray tin has an entropy of –7.5 J K^{-1}.

29. Which of the following statements is(are) **FALSE**?

(i) All spontaneous processes increase the total entropy of the universe.
(ii) $\Delta G_{sys} < 0$ for all spontaneous processes.
(iii) The normal boiling point of a liquid is given by $\Delta H_{vaporization} / \Delta S_{vaporization}$.
(iv) At a given temperature, a reaction proceeds spontaneously in the forward direction if its reaction quotient is larger than its equilibrium constant.

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

30. Consider the reaction $Si(s) + 2\ H_2(g) \rightarrow SiH_4(g)$. Use the data below to identify the **TRUE** statement(s).

(i) $\Delta S° > 0$ for the forward reaction.
(ii) The reverse reaction is spontaneous at all temperatures.
(iii) If $P(H_2) = 100$ atm at equilibrium at 25 °C, then $P(SiH_4) = 1.10 \times 10^{-6}$ atm.
(iv) If $P(H_2) = 100$ atm at equilibrium at 25 °C, then $P(SiH_4) = 1.10 \times 10^{-4}$ atm.

Data:

$\Delta H_f°(SiH_4,g) = 34.3$ kJ mol^{-1} $S°(SiH_4,g) = 204.62$ J K^{-1} mol^{-1}
$S°(H_2,g) = 130.68$ J K^{-1} mol^{-1} $S°(Si,s) = 18.83$ J K^{-1} mol^{-1}

.

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

Name: _____ Student number: _____

Extra space for rough work:

Name: _____ Student number: _____

Extra space for rough work:

Name: _____ Student number: _____

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

$R = 8.3145\ \text{J K}^{-1}\ \text{mol}^{-1} = 0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1}$

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

$c = 2.9979 \times 10^{8}\ \text{m s}^{-1}$

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

$m_e = 9.10 \times 10^{-31}\ \text{kg}$

density(H_2O, l) = 1.00g/mL

Specific heat of H_2O(s) = 2.03 J / g·°C

$\Delta H^{o}_{fus}[H_2O] = 6.01\ \text{kJ mol}^{-1}$

Specific heat of H_2O(l) = 4.18 J / g·°C

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

1 atm = 101.325 kPa = 760 mm Hg

0°C = 273.15 K

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

$1\ \text{m} = 10^9\ \text{nm} = 10^{10}\ \text{Å}$

$1\ \text{cm}^3 = 1\ \text{mL}$

$1\ \text{g} = 10^3\ \text{mg}$

1 Hz = 1 cycle/s

De Broglie wavelength:

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

Hydrogen atom energy levels:

$E_n = -R_H / n^2 = -2.178 \times 10^{-18}\ \text{J} / n^2$

Gibbs free energy of reaction: $\Delta G = \Delta G° + RT \ln Q$

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

Solubility Guidelines for Common Ionic Solids

TABLE 5.1 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 (with some exceptions for Li^+) and the NH_4^+ cation are soluble.
2. Nitrates, acetates, and perchlorates are soluble.
3. Salts of silver, lead, and mercury(I) are insoluble.
4. Chlorides, bromides, and iodides are soluble.
5. Carbonates, phosphates, sulfides, oxides, and hydroxides are insoluble (sulfides of group 2 cations and hydroxides of Ca^{2+}, Sr^{2+}, and Ba^{2+} are slightly soluble).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

Name: ____________________ Student number: ______________

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
		Transition Metals															
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]												

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