Name: _____ Student number: _____

Chemistry 1A03 **FINAL EXAM** **Dec 14, 2016**

McMaster University **VERSION 1**

Instructors: L. Chen, L. Davis, D. Emslie, A. Hitchcock Duration: 150 minutes

This test contains 11 sheets of paper, printed on both sides, for a total of 22 numbered pages. There are **30** multiple-choice questions appearing on pages numbered 3 to 17. Pages 18-20 are blank pages for rough work. Page 21 includes some useful data and equations; there is a periodic table on page 22. You may tear off the last sheet to view the data/equations and the periodic table.

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** 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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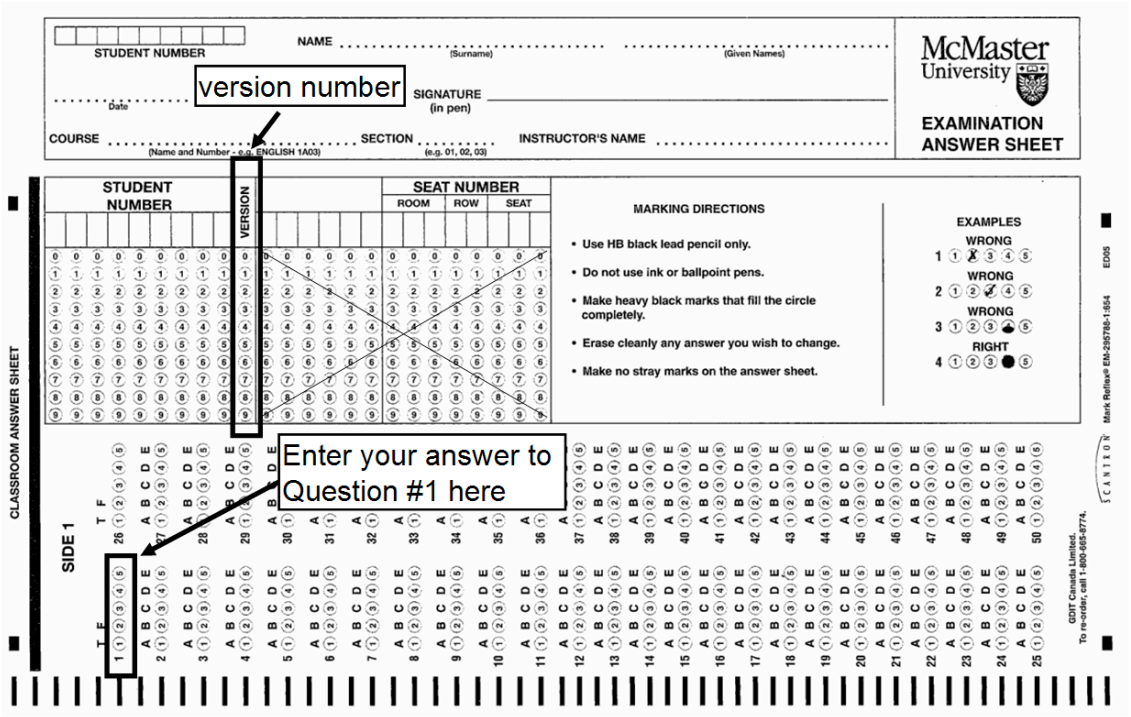
OMR EXAMINATION – STUDENT INSTRUCTIONS

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 **pH** of a 0.451 M solution of HNO_3 ?

   A) 1.024
   B) 0.346
   C) 1.253
   D) 0.428
   E) 0.847

2. Which of the following molecules or ions can exist as **more than one isomer** ?

   i) SeF_6
   ii) SeF_3Cl_3
   iii) SeF_5Cl
   iv) XeF_2Cl_2
   v) $PH_2Cl_2^+$

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

3. Which of the following statements regarding a 0.214 M aqueous solution of propionic acid (CH_3CH_2COOH, $K_a = 1.34 \times 10^{-5}$) are **FALSE**?

   i) The percent dissociation of propionic acid is greater than 0.800%.
   ii) The conjugate base of propionic acid is $CH_3CH_2COO^-$.
   iii) The pH of this solution is between 2.76 and 2.78.
   iv) The "small x" approximation cannot be used in this calculation.
   v) Propionic acid is a weaker acid than acetic acid (CH_3COOH, $K_a = 1.76 \times 10^{-5}$).

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

4. Which of the following relationships concerning relative **acid strength** are **FALSE** ?

   i) $HI < HCl$
   ii) $HClO_3 < HClO_4$
   iii) $H_2O < NH_3$
   iv) $HF < HBr$
   v) $CBr_3COOH < CCl_3COOH$

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

5. What is the minimum amount of energy, in **joules**, that must be **absorbed** to convert all of the atoms present in **1.0 mg** of gaseous Rb to Rb^+ ? The first ionization energy of Rb is 403.0 kJ mol^{-1}.

   A) 2.9
   B) 4.7
   C) 0.21
   D) 3.4
   E) 4.0

6. Which **one** of the following statements concerning **equilibrium** is **FALSE ?**

   A) Removing a reactant or product can cause *K* to change.
   B) When $Q > K$ the reaction will shift towards reactants.
   C) The activity of pure solids is 1.0.
   D) If the equilibrium constant for a chemical reaction is K_f in the forward direction, then the equilibrium constant for the reverse reaction is K_f^{-1} .
   E) In equilibrium constant expressions involving gases, the partial pressure of each gas is used instead of concentration.

7. For Experiment #3, The Determination an Equilibrium Constant, a student created a calibration curve relating the absorbance of $FeSCN^{2+}$ (aq) at 447 nm to the concentration of $FeSCN^{2+}$ (aq). The slope of this plot is 3808 M^{-1}. When the student mixed 10.0 mL of 0.00150 M Fe^{3+} (aq) with 5.00 mL of 0.00150 M SCN^- (aq) an absorbance of 0.650 was observed. What is the **equilibrium constant** for the reaction ?

   A) 173
   B) 948
   C) 856
   D) 312
   E) 625

8. Which **one** of the following statements about **BiF_2Cl_3** is **FALSE** ?

   A) Three isomers are possible.
   B) The molecule has a trigonal bipyramidal electron pair geometry.
   C) All isomers of BiF_2Cl_3 are polar.
   D) Bismuth in BiF_2Cl_3 does not obey the octet rule.
   E) The Bi-F bonds are more polar than the Bi-Cl bonds.

9. NO_2 (g) reacts with liquid water to form liquid nitric acid and NO (g). A 670 mL volume of NO_2 (g) at 1.5 atm and 25.0 °C, reacts with 0.090 g of H_2O (l). What is the **mole fraction of NO_2** in the **final gas mixture** ?

   A) 0.39
   B) 0.84
   C) 0.17
   D) 0.21
   E) 0.53

10. Which of the following statements about Lewis structures are **FALSE** ?

   i) BF_3 is trigonal planar.
   ii) XeF_2 has an octet of electrons at xenon.
   iii) SO_3 is a non-polar molecule.
   iv) NO_3^- has 3 resonance structures.
   v) BrF_3 is trigonal planar.

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

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

A) The conjugate base of a weak acid is a strong base.
B) The conjugate base of a weak acid is a stronger base than the conjugate base of a strong acid.
C) A strong acid is completely dissociated in water.
D) The K_b for the conjugate base of a weak acid is equal to K_w/K_a .
E) A strong monoprotic acid produces a hydronium ion and a spectator ion.

12. Which **one** of the following is **NOT an allowable set of quantum numbers** for an electron in a ground state Mg atom ?

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

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13. Aluminum metal has a specific heat capacity of 0.900 J g^{-1} °C^{-1}. Calculate the amount of **heat** in **kJ** that is required to raise the temperature of 10.5 moles of Al from 30.5 °C to 225 °C.

A) 2.41
B) 65.1
C) 57.3
D) 1.70
E) 49.6

14. Carbon tetrachloride, CCl_4, is an important commercial solvent. It can be prepared by the following reaction:

$$CS_2\,(l) + 3\,Cl_2\,(g) \rightarrow CCl_4\,(l) + S_2Cl_2\,(l)$$

Use Hess's law and the **appropriate** data from the following list to determine the **standard enthalpy of reaction ($\Delta_r H°$)** in **kJ mol^{-1}** for the above reaction.

	$\Delta_r H°$ (kJ mol^{-1})
$CS_2\,(l) + 3\,O_2\,(g) \rightarrow CO_2\,(g) + 2\,SO_2\,(g)$	−1077
$2\,S\,(s) + Cl_2\,(g) \rightarrow S_2Cl_2\,(l)$	−58.2
$C\,(s) + 2\,Cl_2\,(g) \rightarrow CCl_4\,(l)$	−135.4
$S\,(s) + O_2\,(g) \rightarrow SO_2\,(g)$	−296.8
$SO_2\,(g) + Cl_2\,(g) \rightarrow SO_2Cl_2\,(l)$	+97.3
$C\,(s) + O_2\,(g) \rightarrow CO_2\,(g)$	−393.5
$CCl_4\,(l) + O_2\,(g) \rightarrow COCl_2\,(g) + Cl_2O\,(g)$	−5.2

A) −143
B) −284
C) −98.2
D) −127
E) −66.7

15. In Experiment # 4, The Measurement of a Change in Enthalpy, the reaction of 0.19 g of magnesium with excess HNO_3 (aq), caused 0.79 g of ice to melt. What is the **heat of reaction per mole of Mg** (in kJ mol^{-1}) ? [ΔH_{fus}(ice) = 333 J g^{-1}]

A) +95
B) +34
C) −34
D) −62
E) +62

16. Which **one** of the following processes does NOT involve the transfer of energy via **work** when the reaction is carried out at constant pressure in a vessel open to the atmosphere?

A) Combustion of solid sucrose ($C_{12}H_{22}O_{11}$) in oxygen gas to form carbon dioxide gas and liquid water.
B) Conversion of gaseous nitrogen dioxide to gaseous dinitrogen tetroxide.
C) Reaction of solid copper(II) sulfate and water vapor to form solid copper(II) sulfate pentahydrate.
D) Reaction of nitrogen monoxide gas and oxygen gas to form gaseous nitrogen dioxide.
E) Decomposition of solid calcium carbonate to solid calcium oxide and carbon dioxide gas.

17. A 100 g block of substance A is heated to 100 °C and dropped into Beaker A containing 100 mL of water at 25 °C. A 100 g block of substance B is also heated to 100 °C and dropped into beaker B containing 100 mL of water at 25 °C. The final temperature of substance A is greater than the final temperature of substance B. **Which substance has the greater specific heat capacity ?** Assume there is no phase change of either substance A or substance B between 25 °C and 100 °C. Please note: there is no selection E for this question.

    A) substance B.
    B) substance A.
    C) substance A and B have the same specific heat capacity.
    D) there is not enough information to determine which substance has the greater specific heat capacity.

18. Find the **standard enthalpy of formation (**$\Delta_f H°$) of ethylene, $C_2H_4\,(g)$, in **kJ mol^{-1}** given the following data:

    heat of combustion of $C_2H_4\,(g) = -1411$ kJ mol^{-1}
    $\Delta_f H°[CO_2\,(g)] = -393.5$ kJ mol^{-1}
    $\Delta_f H°[H_2O\,(l)] = -285.8$ kJ mol^{-1}

    A) 52.4
    B) 2.77×10^3
    C) 3.41×10^3
    D) 87.3
    E) 731

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19. The K_a for benzoic acid in water is 6.50×10^{-5} at 298 K. What is $\Delta G°$ (in **kJ mol^{-1}**) for dissociation of benzoic acid in aqueous solution ?

A) −23.9
B) +52.4
C) −34.4
D) −52.4
E) +23.9

20. A chemical reaction is in a state such that Q > K. Under this condition, ΔG for the forward reaction, $\Delta G_{forward}$, would have **what sign**, and **in what direction would the reaction proceed** ?

A) $\Delta G_{forward}$ = positive; spontaneous in the forward direction
B) $\Delta G_{forward}$ = positive; spontaneous in the reverse direction
C) $\Delta G_{forward}$ = negative; spontaneous in the forward direction
D) insufficient information is provided to answer the question
E) $\Delta G_{forward}$ = negative; spontaneous in the reverse direction

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21. Which **one** of the following statements about enthalpy and entropy is **FALSE** ?

A) The standard molar entropy of NCl_3 gas is greater than that of NH_3 gas.
B) For a spontaneous process, ΔH can be positive or negative.
C) The standard molar entropy of liquid $H_3C\text{-}CH_2\text{-}C(CH_3)_3$ is greater than the standard molar entropy of liquid $H_3C\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3$.
D) The sign of ΔS_{rxn} is independent of the sign of ΔH_{rxn}.
E) Dissolving NH_4NO_3 in water results in an increase in the entropy of the system.

22. Which **one** of the following reactions will be <u>spontaneous</u> at **high temperature**, but <u>not spontaneous</u> at **low temperature** ?

A) $NH_3\ (g) \rightarrow NH_3\ (l)$
B) $2\ Li\ (g) \rightarrow Li_2\ (g)$
C) $Pb\ (s) + 3\ N_2\ (g) \rightarrow Pb(N_3)_2\ (s)$
D) $NH_4NO_3\ (s) \rightarrow NH_4^+\ (aq) + NO_3^-\ (aq)$
E) $2\ NI_3\ (s) \rightarrow N_2\ (g) + 3\ I_2\ (s)$

23. Potassium chlorate, $KClO_3$, decomposes via the reaction:

$$2\ KClO_3\ (s) \rightarrow 2\ KCl\ (s) + 3\ O_2\ (g)$$

Use the thermochemical information given below to calculate the **standard Gibbs free energy in kJ** for the decomposition of 2 moles of $KClO_3$ at 298 K.

	$KClO_3$ (s)	KCl (s)	O_2 (g)
$\Delta H_f°$ (kJ mol^{-1})	–391.2	–435.9	0
$S°$ (J mol^{-1} K^{-1})	143.0	82.7	205.0

A) –236.7
B) –57.9
C) +12.0
D) –122.0
E) +111.3

24. The melting point of uranium is 1132 °C and the enthalpy of fusion (i.e. melting) of uranium is 9.14 kJ mol^{-1}. What is the **entropy of fusion** (in J mol^{-1} K^{-1}) of uranium ?

A) −6.50
B) +14.3
C) −14.3
D) +154
E) +6.50

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25. Given the following standard reduction potentials, $E°_{red}$, which species has the **greatest tendency to be oxidized** ?

$S\,(s) + 2\,H^+ + 2e^- \rightarrow H_2S\,(g)$ $\quad E°_{red} = +0.144$ V
$O_2\,(g) + 4\,H^+ + 4e^- \rightarrow 2\,H_2O\,(l)$ $\quad E°_{red} = +1.229$ V
$Sn^{2+}\,(aq) + 2e^- \rightarrow Sn\,(s)$ $\quad E°_{red} = -0.137$ V

A) $O_2\,(g)$
B) $S\,(s)$
C) $Sn\,(s)$
D) $H_2S\,(g)$
E) $Sn^{2+}\,(aq)$

26. In aqueous acid solution, dichromate, $Cr_2O_7^{2-}\,(aq)$, reacts with zinc metal to produce $Cr^{3+}\,(aq)$ and $Zn^{2+}\,(aq)$ ions. When the reaction is balanced so that the stoichiometric coefficients are the smallest possible integers, what is **the stoichiometric coefficient for H^+** ?

A) 8
B) 14
C) 6
D) 12
E) 10

27. Given the following data, what species would act as the **cathode** electrode in the **most spontaneous reaction** that can be constructed from the following half-reactions ?

$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$ $E°_{red} = +0.800$ V
$Cu^{+}(aq) + e^{-} \rightarrow Cu(s)$ $E°_{red} = +0.520$ V
$Al^{3+}(aq) + 3e^{-} \rightarrow Al(s)$ $E°_{red} = -1.662$ V

A) Al
B) Ag^{+}
C) Cu
D) Al^{3+}
E) Ag

28. A student wishes to make an electrochemical cell with $\mathbf{E_{cell} = 1.0645\ V}$, based on **Zn (s) | Zn^{2+} (aq) || Cu^{2+} (aq) |Cu (s)** at 298 K for which $\mathbf{E°_{cell} = 1.1030\ V}$. If both metal ion solutions are initially of equal molarity, **which solution needs to be decreased in concentration** and **by what factor** to produce a cell with $\mathbf{E_{cell} = 1.0645\ V}$?

A) Zn^{2+} (aq), decreased by 20
B) Cu^{2+} (aq), decreased by 5
C) Zn^{2+} (aq), decreased by 5
D) It is not possible to create a cell with this voltage based on these metals.
E) Cu^{2+} (aq), decreased by 20

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29. Given the following data, what is **$\Delta G°_{cell}$ (in kJ), per mole of reducing agent,** for the **most spontaneous cell** that can be constructed from the following half-reactions ? (1 Joule = 1 Coulomb × 1 Volt)

$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$ $\quad E°_{red} = +0.800$ V
$Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s)$ $\quad E°_{red} = -0.763$ V
$Sn^{2+}(aq) + 2e^{-} \rightarrow Sn(s)$ $\quad E°_{red} = -0.137$ V

A) −217.9
B) −467.3
C) −663.0
D) −158.2
E) −301.6

30. Which **one** of the following statements regarding electrochemistry is **FALSE ?**

A) A reducing agent provides electrons to the oxidizing agent.
B) The purpose of an inert electrode is to facilitate the transfer of electrons.
C) In an electrolysis experiment, a voltage is applied to make a non-spontaneous reaction occur.
D) In a concentration cell based on Cu^{2+} ions, electrons move from higher to lower concentration solutions.
E) In a galvanic cell, electrons travel through the external circuit from the anode to the cathode.

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Extra space for rough work (1)

Name: _____ Student number: _____

Extra space for rough work (2)

Name: _____ Student number: _____

Extra space for rough work (3)

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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

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