Name: _____ **Student number:** _____

Chemistry 1E03 **Final Exam Version 1** **December 2012**

McMaster University

Instructors: Drs. R.S. Dumont, J. Landry

Duration: 180 minutes

This test contains 20 numbered pages printed on both sides. There are **35** multiple-choice questions appearing on pages numbered 3 to 15. Pages 16, 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 70. There is **no** additional 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 periodic tables or any aids, other than those provided, is not allowed.

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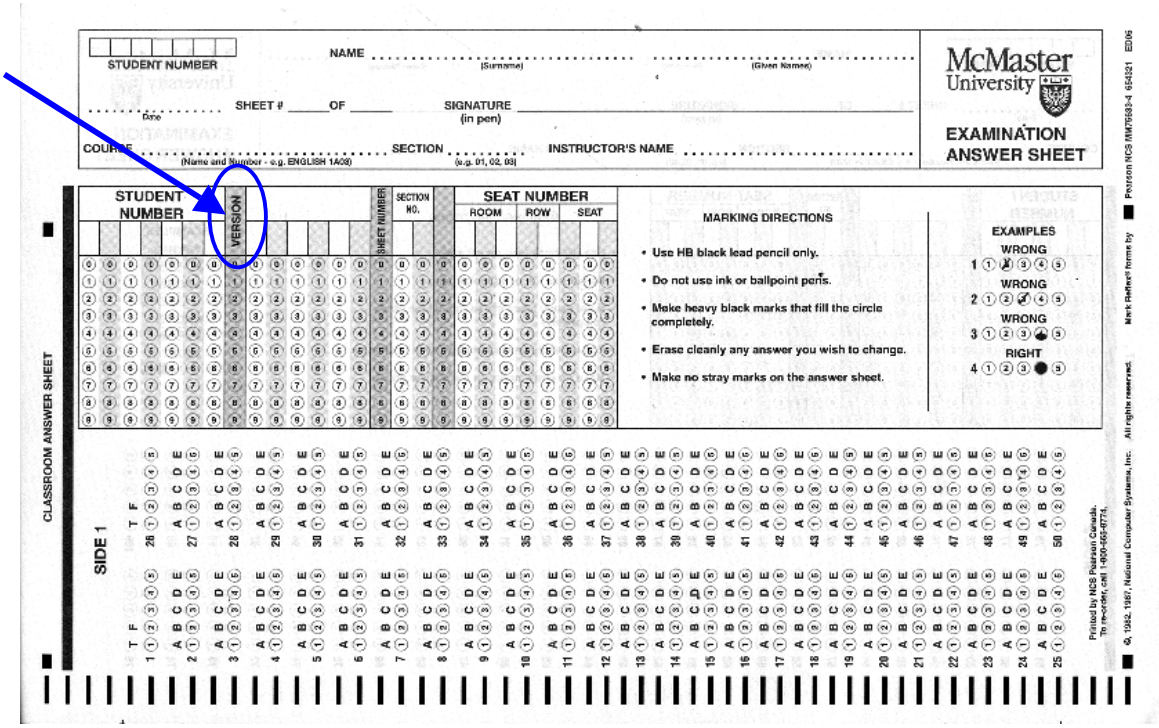
OMR EXAMINATION – STUDENT INSTRUCTIONS

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, ~~(section number, instructor 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** (~~and course section number~~) in the space provided and <u>fill in the corresponding bubble numbers underneath</u>.
3. Answers: mark only **ONE** choice from the alternatives (~~1,2,3,4,5 or~~ A,B,C,D,E) provided for each question. ~~If there is a True/False question, enter response o 1 (or A) as True, and 2 (or B) as False.~~ 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".



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1. Which atom has the greatest (most negative) **electron affinity** of As, Cs, F, N, Ne?
.
A) As
B) Cs
C) N
D) Ne
E) F

2. If three solutions containing 1.635 g of $NaClO_4$, 2.362 g of Rb_2S and 0.796 g of $CuCl_2$, respectively, are mixed together, what is the **mass** of the precipitate formed (i.e. if a precipitate forms)?
.
A) 1.267 g
B) 3.673 g
C) 2.396 g
D) 0.566 g
E) A precipitate does not form

3. Which one of the following statements is **FALSE**?
.
A) Be is smaller than Li.
B) Be has a larger ionization energy than Li.
C) The ground state electron configuration of an oxygen atom has two unpaired electrons.
D) Al has a larger ionization energy than B.
E) O^{2-} is larger than F^-.

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4. The perxenate anion, XeO_6^{4-}, has been isolated in the form of several salts including Na_4XeO_6. Which of the following statements is **FALSE** regarding the charge-minimized Lewis structure of XeO_6^{4-}?

   A) There are no lone electron pairs on Xe
   B) There are 16 electrons involved in bonds
   C) The average formal charge on oxygen is –2/3
   D) There are exactly 6 resonance structures for XeO_6^{4-}
   E) The Xe-O bond order is 4/3

5. When the following reaction is balanced in **basic** media, the coefficient for **OH^-** is:
   $MnO_4^- + S_2O_4^{2-} \rightarrow MnO_2 + SO_4^{2-}$

   A) 3
   B) 0
   C) 4
   D) 2
   E) 1

6. Which **one** of the following is the **correct** electron configuration for the **ground state** of the Sn atom?

   A) [Kr] $5s^2 5p^2$
   B) [Kr]
   C) [Kr] $5s^2 4d^{10} 4p^6$
   D) [Xe]
   E) [Kr] $5s^2 4d^{10} 5p^2$

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7. A student creates an electrochemical cell based on 5.00×10^{-3} mol of both O_2 (g) and H_2S (g) in separate 2.0 L vessels outfitted with Pt (s) electrodes in acidic solution at 298 K. What is the **voltage** produced?

.

$S(s) + 2H^+ + 2e^- \rightarrow H_2S\ (g)$ $\quad E^o = 0.144$ V

$O_2(g) + 4H^+ + 4e^- \rightarrow 2\ H_2O\ (l)$ $\quad E^o = 1.229$ V

.

A) 1.002 V
B) 1.145 V
C) 0.984 V
D) 1.088 V
E) 1.031 V

8. What **potential**, in volts, is developed by the following electrochemical cell at 298 K?

$Al(s) \mid Al^{3+}(0.00100\ M) \parallel Cu^{2+}(0.00100\ M) \mid Cu(s)$

$A1^{3+}(aq) + 3e^- = Al(s)$ $\quad E°_{red} = -1.66$V

$Cu^{2+}(aq) + 2e^- = Cu(s)$ $\quad E°_{red} = +0.34$ V

(Hint: balance the cell reaction before you proceed.)

.

A) 2.01
B) 2.07
C) 1.95
D) 1.97
E) 2.00

Continued on next page

9. A **concentration cell** is used to measure the concentration of Zn^{2+} in a saturated solution of $ZnCO_3$. The saturated solution is at the anode, while there is a 1.0 mol L^{-1} solution of $Zn(NO_3)_2$ at the cathode. If the measured voltage of the cell is 0.321 V at 298 K, what is the **molar solubility** of $ZnCO_3$ at 298 K in mol L^{-1}?

.

A) 2.1×10^{-10}
B) 3.6×10^{-12}
C) 5.1×10^{-9}
D) 7.8×10^{-12}
E) 1.4×10^{-11}

10. Identify the **ONE FALSE** statement regarding the electrochemical cell

$$Co(s) \mid CoSO_4\,(1.00\ M) \parallel Fe(NO_3)_3\,(1.00\ M)\ ,\ Fe(NO_3)_2\,(1.00\ M) \mid Pt(s)\ ,$$

for which $E_{cell} = +1.05$ V. The cell contains a KCl salt bridge.

.

A) The Co^{2+} concentration decreases during operation of the cell.
B) Increasing the concentration of $CoSO_4(aq)$ reduces the cell potential.
C) Fe^{3+} ions migrate toward the Pt(s) electrode.
D) K^+ ions from the salt bridge migrate to the cathode.
E) Pt(s) is the cathode.

11. Determine the **FALSE** statement regarding the following cell diagram:

$Zn(s) \mid Zn(NO_3)_2\,(aq;\ 1.0\ M) \parallel Cu(NO_3)_2(aq;\ 1.0\ M) \mid Cu(s)$

.

A) NO_3^- is a spectator ion
B) || represents the salt bridge
C) Cu (s) is being oxidized.
D) Zinc is the anode
E) At 25°C this is a standard electrochemical cell.

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12. Determine $E°_{cell}$ for the reaction: $2\ Ag^{+} + Mg \rightarrow 2\ Ag + Mg^{2+}$. The half reactions are:

.

$Mg^{2+}(aq) + 2\ e^{-} \rightarrow Mg(s)$ $\quad E° = -2.356$ V

$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$ $\quad E° = 0.800$ V

.

A) −1.556 V
B) 3.956 V
C) −2.356 V
D) 1.556 V
E) 3.156 V

13. How much **heat** (in kJ) is required to convert 36.0 g of liquid H_2O at 50.0°C to gaseous H_2O at 100.0°C? $\Delta H_{vaporization}$ for H_2O (l) = 44.0 kJ/mol. The specific heat of water is 4.184 J g^{-1} $°C^{-1}$.

.

A) 47.8
B) 95.5
C) 7.65×10^{3}
D) 78.0
E) 8.56

14. A student uses an ice calorimeter to monitor an acid base neutralization reaction. If a limiting amount of monoprotic acid, 0.20 mol, is added to excess base, causing 5.5 g of ice to melt (heat of fusion for ice = 333 J g^{-1}), what is the **molar heat of neutralization**?

.

A) –1.8 kJ
B) –320 kJ
C) –25 kJ
D) –48 kJ
E) –9.2 kJ

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15. 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) Pumping additional $N_2(g)$ into the container increases the amount of solid ammonium nitrite.
B) Reducing the volume of the container increases the amount of $NH_4NO_2(s)$.
C) Removing water (via a drying agent) 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) Adding more $NH_4NO_2(s)$ to the container does not affect the partial pressure of $N_2(g)$.

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

$$2\ C_2H_4(g) \rightarrow C_2H_2(g) + C_2H_6(g)$$

Bond enthalpies (kJ mol^{-1}): C-C 348; C=C 619; C≡C 812; C-H 413

.

A) –78
B) +29
C) –166
D) +78
E) –29

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17. A vessel initially contains pure $N_2O_4(g)$ with partial pressure 1.00 atm. N_2O_4 dissociates according to the following equilibrium:

$$N_2O_4(g) \rightleftharpoons 2\ NO_2(g) \qquad K = 0.148 \text{ at } 25°C$$

What is the total pressure in the vessel when the gas mixture reaches equilibrium?

.

A) 0.93
B) 1.65
C) 1.00
D) 1.17
E) 0.28

18. Considering the data below, identify the **FALSE** statement(s).

$\Delta H_f°$ of B(g) = 563 kJ mol^{-1}
bond enthalpy (F-F) = 159 kJ mol^{-1}
bond enthalpy (B-F) = 646 kJ mol^{-1}

i. $\Delta H° = -2273$ kJ mol^{-1} for $2\ B(s) + 3\ F_2(g) \rightarrow 2\ BF_3(g)$
ii. $B(s) \rightarrow B(g)$ is an endothermic process.
iii. $\Delta H° = -159$ kJ mol^{-1} for $F_2(g) \rightarrow 2\ F(g)$

.

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

 Continued on next page

19. As it is written, is the following reaction **endothermic** or **exothermic,** and is work done **on** or **by** the system?

$$C(s) \rightarrow C(g)$$

.

A) exothermic; by
B) exothermic; on
C) endothermic; on
D) $\Delta H = 0$; by
E) endothermic; by

20. The following reaction proceeds essentially to completion. Which of the following species is the **strongest** acid?

$$LiNH_2(s) + H_2O(l) \rightarrow NH_3(g) + LiOH(s)$$

.

A) NH_3
B) LiOH
C) H_2O
D) Not enough information
E) $LiNH_2$

21. A 0.35 M solution of a weak monoprotic acid has a pH of 2.18.
What is the **% dissociation** of the acid?

.

A) 0.83 %
B) 1.9 %
C) 2.1 %
D) 58 %
E) 4.3 %

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22. When the **conjugate base of a weak acid** (in the form of the sodium salt) is dissolved in water, one can conclude:

.

A) pH > 7
B) There is 100% conversion of conjugate base back to weak acid.
C) $[A^-] < [HA]$
D) $[H_3O^+] > [OH^-]$
E) $K_a = K_b$

23. Which of the following is the **strongest base**?

.

A) $HSeO_3^-$
B) $HSeO_4^-$
C) ClO_4^-
D) HSO_3^-
E) HSO_4^-

24. NaF (2.6 g) is dissolved in 250 mL of water. What is the **pH** of the solution?
$K_b(F^-) = 1.5\times10^{-11}$

.

A) 6.15
B) 11.68
C) 8.29
D) 5.34
E) 10.45

 Continued on next page

25. Which of the following, when dissolved in water would **NOT dissociate 100%**?
.
A) HI
B) HCl
C) NH_4^+
D) $HClO_4$
E) HBr

26. The K_{sp} of $Ca(OH)_2 = 5.5\times10^{-6}$. What is the **pH** of a saturated solution of calcium hydroxide?
.
A) 6.65
B) 8.93
C) 12.35
D) 14.19
E) 11.72

27. What is the **conjugate base** of OH^-?
.
A) O^{2-}
B) H_2O
C) H_3O^+
D) OH^- does not have a conjugate base
E) O^-

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28. Choose the **FALSE** statement regarding entropy.

.

A) The processes of melting and boiling are accompanied by positive changes of entropy of the substance.
B) The change in entropy between initial and final states does not depend on the path taken between them.
C) At $T = 0$ K, a perfect crystal has zero entropy.
D) A spontaneous process always implies an increase in the entropy of the universe.
E) Entropy is an intensive property. In other words, it does not depend on the amount of substance present.

29. Identify the reaction with the **largest positive $\Delta S°$**.

.

A) $N_2(g) + 3\ H_2\ (g) \rightarrow 2\ NH_3(g)$
B) $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$
C) $PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$
D) $H_2O(s) \rightarrow H_2O(g)$
E) $KClO_4(s) + 4\ C(s) \rightarrow KCl(s) + 4\ CO(g)$

30. Choose the **FALSE** statement.

.

A) A process for which $\Delta H_{sys} < 0$ is spontaneous at sufficiently low temperatures.
B) $\Delta G_{sys} = 0$ for melting of copper at the melting point of copper.
C) Process for which $\Delta H_{sys} > 0$ and $\Delta S_{sys} < 0$ are not spontaneous at any temperature.
D) A process for which $\Delta S_{sys} > 0$ is spontaneous at sufficiently high temperatures.
E) $\Delta G_{sys} < 0$ for melting of copper at temperatures below the melting point of copper.

Continued on next page

31. In the lab you find that sulfur dioxide reacts with water to give an acidic solution. The reaction is

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$

Use the thermochemical information given below to calculate the **standard Gibbs free energy** (in kJ mol^{-1}) of this hydration reaction at 298 K.

	$H_2O(l)$	$SO_2(g)$	$H_2SO_3(aq)$
$\Delta H_f°$ / (kJ mol^{-1})	–285.83	–296.83	–627.98
$S°$ / (J $mol^{-1}K^{-1}$)	69.91	248.22	132.38

.

A) –10.0
B) –90.7
C) +55.3
D) +10.0
E) +90.7

32. Which of the following are **TRUE** statements regarding a **spontaneous reaction** at constant temperature and pressure?

i. $\Delta S_{univ} < 0$
ii. $\Delta G_{sys} < 0$
iii. $\Delta S_{sys} > \Delta H_{sys} / T$
iv. $Q > K$

.

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

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33. The melting point of tungsten, 3407°C, is the second highest among the elements. The enthalpy of fusion (i.e. melting) of tungsten is 35.2 kJ mol^{-1}. What is the **entropy of fusion (in J mol^{-1} K^{-1})** of tungsten?

.

A) –11.7
B) +109
C) +9.56
D) –9.56
E) +11.7

34. Identify the **FALSE** statement(s):

i. Mixing together aqueous solutions of NaCl and KCl at constant temperature results in an increase of entropy.
ii. $S°$(chlorine gas) > $S°$(nitrogen gas).
iii. Freezing of water causes an increase in the entropy of the surroundings.

.

A) i, iii
B) i, ii
C) ii, iii
D) none of these statements is false
E) all of the statements are false

35. Calculate the **standard entropy of formation (in J mol^{-1} K^{-1})** of $NH_3(g)$ from the standard entropies given below.

	$N_2(g)$	$H_2(g)$	$NH_3(g)$
S^o / (J $mol^{-1}K^{-1}$)	191.6	130.7	192.5

.

A) +139.4
B) +192.5
C) –99.4
D) –139.4
E) –168.1

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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
$R = 8.3145\ \text{J K}^{-1}\ \text{mol}^{-1} = 0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1}$
$c = 2.9979 \times 10^{8}\ \text{m/s}$
$m_e = 9.10 \times 10^{-31}\ \text{kg}$
Specific heat of water = 4.184 J / g·°C
$\Delta H^{\circ}_{vap}[H_2O] = 44.0\ \text{kJ mol}^{-1}$

$F = 96485\ \text{C/mol}$
$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$
$h = 6.6256 \times 10^{-34}\ \text{Js}$
density(H_2O, l) = 1.00g/mL

1 atm = 101.325 kPa = 760 mm Hg
$1\ \text{J} = 1\ \text{kg m}^2\ \text{s}^{-2} = 1\ \text{kPa L} = 1\ \text{Pa m}^3$
$1\ \text{cm}^3 = 1\ \text{mL}$
1 Hz = 1 cycle/s

0°C = 273.15 K
$1\ \text{m} = 10^9\ \text{nm} = 10^{10}\ \text{Å}$
$1\ \text{g} = 10^3\ \text{mg}$

De Broglie wavelength:
$\lambda = h / mv = h / p$

Hydrogen atom energy levels:
$E_n = -R_H / n^2 = -2.178 \times 10^{-18}\ \text{J} / n^2$

Nernst Equation (the last two equations are for $T = 298.15$ K:

$$E_{cell} = E_{cell}^{\circ} - \frac{RT}{zF}\ln Q \quad = E_{cell}^{\circ} - \frac{0.0257\ \text{V}}{z}\ln Q \quad = E_{cell}^{\circ} - \frac{0.0592\ \text{V}}{z}\log_{10} Q$$

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

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.

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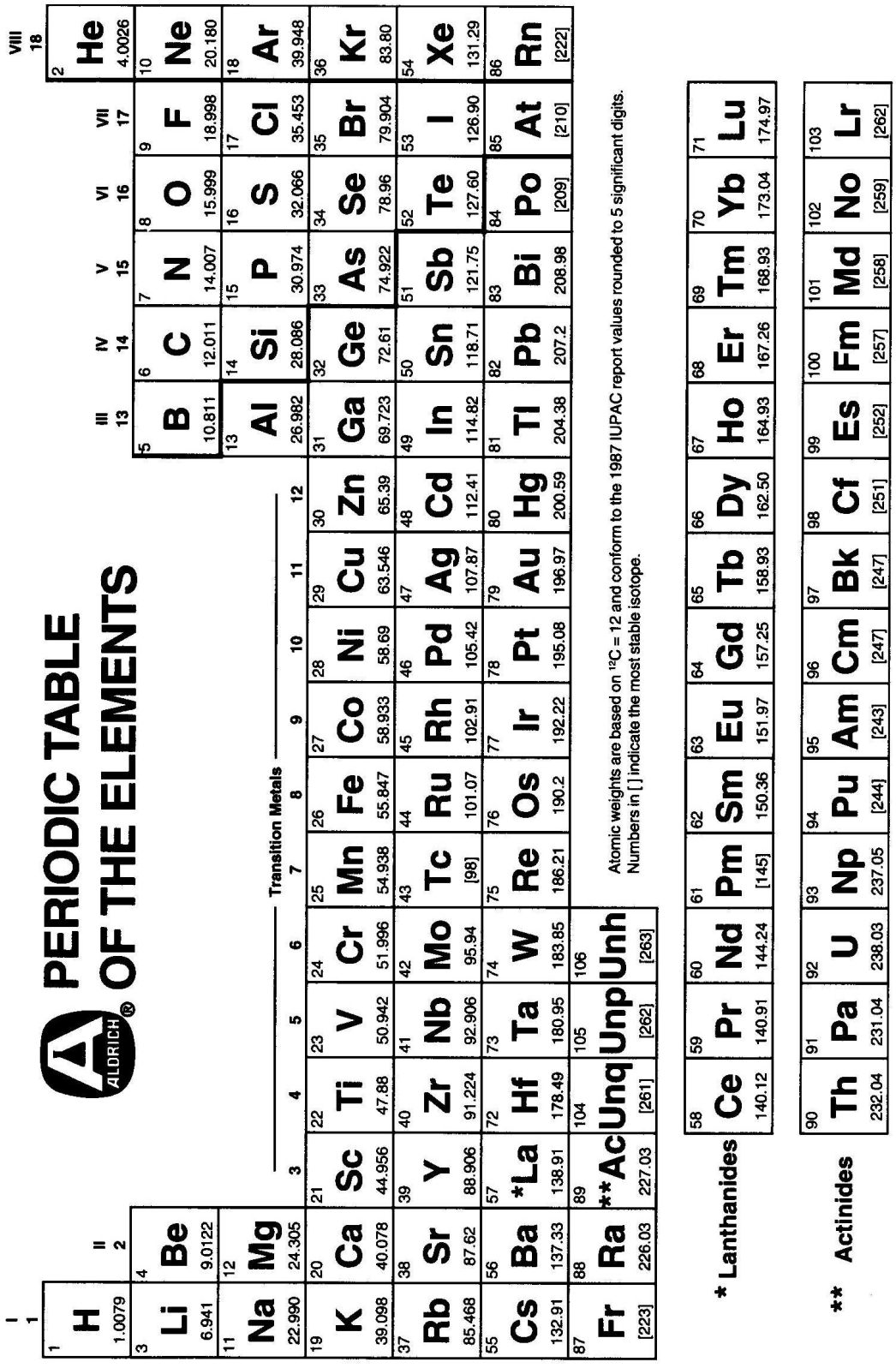

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