Name: _____ Student number: _____

Chemistry 1E03 **Deferred Exam** **February 2014**

McMaster University ***VERSION 1***

Instructors: Drs. R.S. Dumont, A.P. Hitchcock & J.C. Landry

Duration: 180 minutes

This test contains 23 numbered pages printed on both sides. There are **35** multiple-choice questions appearing on pages numbered 3 to 18. Pages 19, 20 and 21 provide extra space for rough work. Page 22 includes some useful data and equations, and there is a periodic table on page 23. 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 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 HB 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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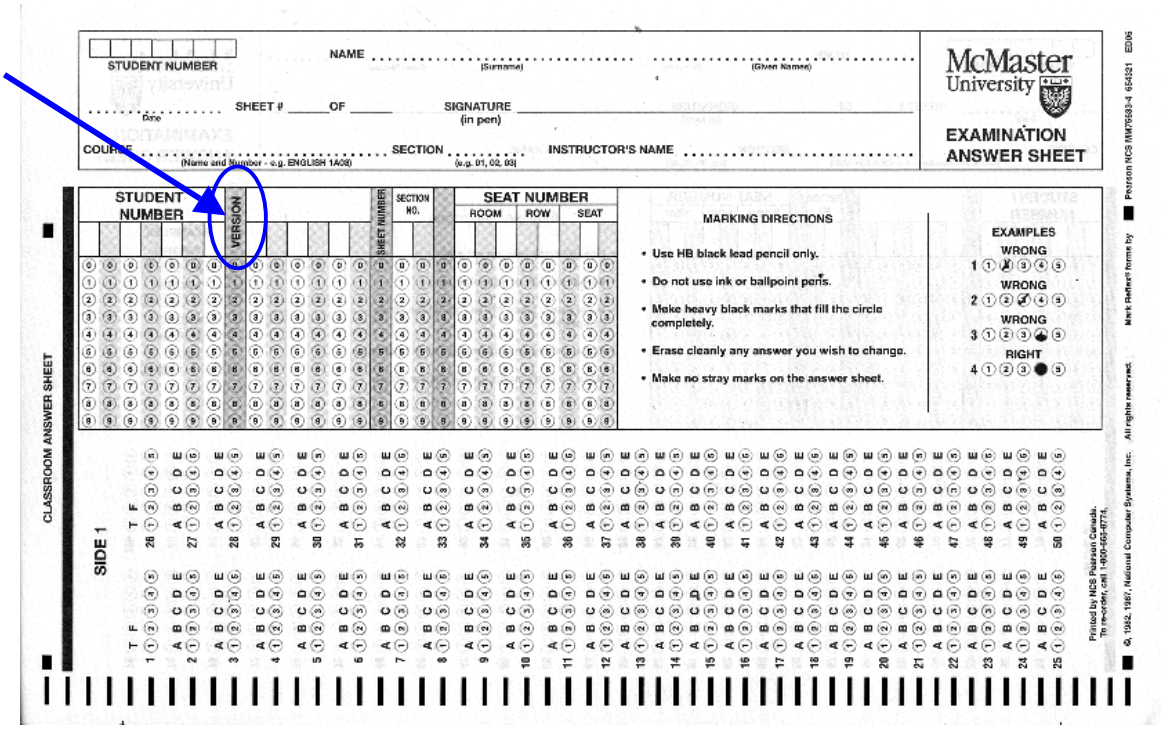
OMR EXAMINATION – STUDENT INSTRUCTIONS

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, 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”.



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1. It takes 492 kJ of energy to remove one mole of electrons from the atoms on the surface of solid gold. What is the **longest wavelength (in nm)** of light capable of doing this?

   .

   A) 817
   B) 743
   C) 243
   D) 123
   E) 404

2. An element is a molecular solid at room temperature. It burns to form a solid oxide, which is acidic when dissolved in water. The element's first ionization energy is higher than either of its neighboring elements (to the left and right) in the periodic table. **Which element is this**?

   .

   A) S
   B) P
   C) Cl
   D) Si
   E) Al

3. In the combustion of phosphorus,

   $$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s),$$

   30.12 kJ of heat is lost from the system, while the volume of gas in the system decreases from 2.00 L to 0.78 L at a constant pressure of 1.00 atm. Assuming this volume change is the only source of work, calculate the resulting **energy change** (in kJ) for the chemical system.

   .

   A) –153.74
   B) +123.6
   C) –30.00
   D) +93.50
   E) –30.24

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4. Identify the **oxidizing agent** in the following reaction.

$$16\ HCl(aq) + 2\ KMnO_4(aq) \rightarrow 5\ Cl_2(g) + 2\ MnCl_2(aq) + 8\ H_2O(l) + 2\ KCl(aq)$$

.

A) $MnCl_2(aq)$
B) $H^+(aq)$
C) $Cl^-(aq)$
D) $K^+(aq)$
E) $MnO_4^-(aq)$

5. Considering the reaction

$2\ B(s) + 3\ F_2(g) \rightarrow 2\ BF_3(g)$

and the data below, identify the **FALSE** statement(s).
enthalpy of formation of B(g) = 563 kJ mol^{-1}
bond enthalpy of F-F bond = 159 kJ mol^{-1}
bond enthalpy of B-F bond = 646 kJ mol^{-1}

(i) The reaction is a redox reaction.
(ii) The reaction of boron and fluorine is endothermic.
(iii) The sublimation of boron is an endothermic process.
(iv) $F_2(g)$ is a highly reactive species.

.

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

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6. Which of the following electron configurations are **excited states** of an element in group 4A?
(i) $1s^2 2s^2 2p^2$ (ii) $1s^2 2s^2 2p^3$ (iii) $1s^2 2s^1 2p^3$ (iv) $1s^2 2s^1 2p^5$ (v) $1s^2 2s^1 2p^2 3d^1$
.
A) ii and iv
B) iii and v
C) i and v
D) i and ii
E) ii and iii

7. Identify the **TRUE** statement(s) among the following:

(i) The breaking of a chemical bond is always endothermic.
(ii) The thermite reaction $Fe_2O_3(s) + 2\ Al(s) \rightarrow 2\ Fe(l) + Al_2O_3(s)$ is endothermic.
(iii) The enthalpy change for $CH_4(g) \rightarrow C(graphite) + 2\ H_2(g)$ equals 4 times the C-H bond energy.
(iv) For any compound $\Delta H_f°(solid) < \Delta H_f°$ (liquid).
.
A) ii, iv
B) ii, iii
C) i
D) i, iv
E) ii

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8. Which of the following statements are **TRUE**?

(i) Alkali metal hydrides produce $H_2(g)$ upon reacting with water.
(ii) Redox reactions between alkali metals (Group 1A) and halogens (Group 7A) produce ionic compounds which are soluble in water.
(iii) HF(aq) is a stronger acid than HCl(aq).
(iv) Mixing saturated aqueous solutions of phosphoric acid and calcium hydroxide produces no visible reaction.

.

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

9. Which of the following molecules are **polar**?

(i) PF_5 (ii) SF_4 (iii) CO_2 (iv) SO_2 (v) H_2SO_4

.

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

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10. Which **one** of the following describes the **shape** of BrF_5?

.

A) octahedral
B) see-saw
C) trigonal bipyramidal
D) square planar
E) square-based pyramidal

11. For the Lewis structure of $ClNO_2$, where nitrogen is the central atom and the other atoms are terminal, choose the **TRUE** statements.

(i) N has 4 bonding electron pairs.
(ii) N has 3 bonding electron pairs and 1 lone electron pair.
(iii) N has a formal charge of +1.
(iv) N has a formal charge of 0.
(v) There are 3 resonance forms.

.

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

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12. Which of **one** the following species has the **most negative average formal charge** on the oxygen atoms?

.

A) ClO_3^-
B) SeO_3^{2-}
C) PO_4^{3-}
D) SeO_4^{2-}
E) SO_2

13. Determine the **equilibrium constant** for the formation of ozone at 298 K,

$$O_2(g) + O(g) \rightleftharpoons O_3(g),$$

from the following data at 298 K:

$$NO_2(g) \rightleftharpoons NO(g) + O(g) \qquad K_1 = 1.6 \times 10^{-48}$$
$$O_3(g) + NO(g) \rightleftharpoons NO_2(g) + O_2(g) \qquad K_2 = 3.4 \times 10^{35}$$

.

A) 3.4×10^{-23}
B) 5.6×10^{53}
C) 1.8×10^{12}
D) 5.4×10^{-13}
E) 2.9×10^{22}

14. Arrange the following substances in order of **increasing** molar **entropy** at 25°C: Ne(g), SO_2(g), Na(s), and H_2O(l)

.

A) $Ne(g) < Na(s) < H_2O(l) < SO_2(g)$
B) $Ne(g) < Na(s) < SO_2(g) < H_2O(l)$
C) $Na(s) < H_2O(l) < Ne(g) < SO_2(g)$
D) $Na(s) < H_2O(l) < SO_2(g) < Ne(g)$
E) $H_2O(l) < SO_2(g) < Na(s) < Ne(g)$

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15. A certain reaction has ΔH = +51.7 kJ, and ΔS = –105 J K^{-1}. **For what temperature(s)** is the reaction **spontaneous**?

.

A) above 219°C
B) all temperatures
C) below 219°C
D) at 219°C only
E) no temperature

16. The standard elemental form of mercury at 300. K is Hg(l). The standard enthalpy of formation for Hg(g) is +60.78 kJ mol^{-1}. The standard entropy of vaporization of mercury is +97.3 J K^{-1} mol^{-1}. Calculate the equilibrium **vapour pressure** (in atm) of mercury at **300. K**. Hint: write an expression for the equilibrium constant.

.

A) 3.16×10^{-6}
B) 0.277
C) 2.59×10^{-5}
D) 0.924
E) 12.7

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17. Which of the following statement(s) is(are) **TRUE?**

(i) Gibbs free energy, Δ*G*, of a reaction varies with temperature.
(ii) A reaction with negative Δ*H*, and negative Δ*S*, is spontaneous at sufficiently high temperature.
(iii) If the equilibrium constant of a reaction is greater than one, the reaction is spontaneous under standard conditions.

.

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

18. At 1000 K, initially pure $NO_2(g)$ decomposes according to

$$2\ NO_2(g) \rightleftharpoons 2\ NO(g) + O_2(g)$$

with an equilibrium constant, $K_p = 158$. At equilibrium, the partial pressure of O_2 is 0.250 atm. What are the **partial pressures (in atm) of NO(g) and NO_2(g)** (in that order) at equilibrium, at 1000 K?

.

A) 0.250, 1.99×10^{-2}
B) 0.125, 1.99×10^{-2}
C) 0.500, 1.99×10^{-2}
D) 0.500, 3.98×10^{-4}
E) 0.125, 3.98×10^{-4}

continued on next page

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19. What is **$\Delta G°$ (in kJ mol^{-1})** for

$$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$$

at 700 K, under standard conditions of 1 atm partial pressure for all gases, given that $K_P = 3.0 \times 10^4$ at 700 K?

.

A) +60
B) –26
C) 0.0
D) +26
E) –60

20. For the reaction,

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g),$$

$\Delta G°$ = –33.2 kJ mol^{-1} at 25°C. In a certain experiment at 25°C, the initial partial pressures are $P(H_2)$ = 0.100 atm, $P(N_2)$ = 0.200 atm, and $P(NH_3)$ = 20.0 atm. What is the initial ΔG (in kJ mol^{-1}) for the reaction under **these conditions**?

.

A) +33.2
B) –5.7
C) –33.2
D) –9.9
E) +2.8

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

.

A) +10.3
B) +104
C) –10.3
D) –9.56
E) +9.56

22. Given the following half reactions, calculate the **standard cell potential** (in V) for the spontaneous cell reaction.

$MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^- \rightarrow Mn^{2+}(aq) + 4\,H_2O(l)$ $\quad E^o_{red} = +1.51$ V
$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$ $\quad E^o_{red} = +0.34$ V

.

A) –1.17 V
B) –1.85 V
C) +1.85 V
D) +1.32 V
E) +1.17 V

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23. Select the **TRUE** statement(s) for the following electrochemical cell:

$$Cu(s)|Cu(NO_3)_2(aq)||AgNO_3(aq)|Ag(s)$$

Data:

$Ag^+(aq) + e^- \rightarrow Ag(s)$ $\quad E°_{red} = + 0.80$ V

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

(i) The concentration of Ag^+ increases in the solution containing the Ag electrode.
(ii) Electrons flow in the external circuit from the Cu to the Ag electrode.
(iii) Ag metal is a stronger reducing agent than Cu metal.
(iv) The Cu electrode is the cathode of the electrochemical cell.
(v) Nitrate anions migrate to the Cu electrode through the salt bridge.

.

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

24. Find the one **FALSE** statement about the electrochemical cell based on the two reduction half-reactions shown below. The concentrations of the ions are $[Al^{3+}] = 0.010$ M, $[Mn^{2+}] = 0.100$ M.

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

$Mn^{2+}(aq) + 2e^- \rightarrow Mn(s)$ $\quad E°_{red} = -1.18$ V

.

A) The observed cell potential is 0.49 V.
B) Al(s) is a stronger reducing agent than Mn(s).
C) The cell diagram is
Al(s) | Al^{3+}(aq, 0.010 M) || Mn^{2+}(aq, 0.100 M) | Mn(s).
D) For the cell balanced equation, $Q = [Al^{3+}] / [Mn^{2+}]$.
E) Six electrons are transferred in the balanced cell reaction.

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25. Given the following half-reactions, identify the **best reducing agent**.

$2\ Hg^{2+}(aq) + 2\ e^- \rightarrow Hg_2^{2+}(s)$	$E°_{red} = +0.92$ V
$N_2(g) + 5\ H^+(aq) + 4\ e^- \rightarrow N_2H_5^+(aq)$	$E°_{red} = -0.23$ V
$Sn^{4+}(aq) + 2\ e^- \rightarrow Sn^{2+}(aq)$	$E°_{red} = +0.13$ V

.

A) $N_2H_5^+(aq)$
B) $Hg_2^{2+}(aq)$
C) $Hg^{2+}(aq)$
D) $Sn^{2+}(aq)$
E) $N_2(g)$

26. You are provided with four 0.035 M metal solutions (listed below) and analytical glassware for diluting samples. You are required to create an electrochemical cell that will produce a potential of +0.814 V. Which **combination of metals** would be the best to start with?

$Au^{3+} + 3e^- \rightarrow Au\ (s)$	$E°_{red} = +1.52$ V
$Ag^+ + e^- \rightarrow Ag\ (s)$	$E°_{red} = +0.800$ V
$Cd^{2+} + 2e^- \rightarrow Cd\ (s)$	$E°_{red} = -0.403$ V
$Mn^{2+} + 2e^- \rightarrow Mn\ (s)$	$E°_{red} = -1.18$ V

.

A) Ag and Ag
B) Cd and Ag
C) Mn and Au
D) Cd and Au
E) Mn and Cd

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27. What is the **potential, in volts,** of the following electrochemical cell?

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

Data:

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

$Ag^{+}(aq) + e^{-} = Ag(s)$ $\quad E°_{red} = +0.80$ V

.

A) 2.52
B) 2.34
C) 2.40
D) 2.58
E) 2.46

28. What is the **pOH** of a 100. mL solution of 0.00059 M HNO_3?

.

A) 10.77
B) 7.00
C) 3.23
D) 4.23
E) 9.77

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29. Heroin, a derivative of morphine, is a powerful analgesic and a powerful narcotic agent. **Calculate K_b** for heroin if the pH of a 1.7 x 10^{-3} M solution was found to be 9.60.

.

A) 3.7 x 10^{-7}
B) 9.5 x 10^{-7}
C) 8.3 x 10^{-7}
D) 1.5 x 10^{-7}
E) 2.3 x 10^{-2}

30. For the six substances listed below, identify how many will form **acidic, neutral or basic solutions** (in that order) when each substance is dissolved in water.

$Ba(OH)_2$ SO_3 HOCl Li_2O $CaBr_2$ HF

.

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

31. What is the **pH** of a monochloroacetic acid ($CH_2ClCOOH$) solution that is 5.00 % dissociated? K_a = 1.35 x 10^{-3}

.

A) 4.17
B) 0.29
C) 2.87
D) 1.30
E) 1.59

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32. Your stomach (volume = 2.5 L) has a pH of 1.00 because of the presence of HCl. **How many grams of $Mg(OH)_2$** (58.3 g mol^{-1}) do you need to add to completely neutralize the acid in your stomach?

.

A) 15 g
B) 2.9 g
C) 21 g
D) 7.3 g
E) 5.8 g

33. A 2.60 g sample of propanoic acid (CH_3CH_2COOH, molar mass = 74.1 g mol^{-1}, $K_a = 1.40 \times 10^{-5}$) was dissolved in water and made up to a final volume of 100. mL in water. **What is the pH** of this solution?

.

A) 3.26
B) 2.66
C) 4.85
D) 2.32
E) 1.82

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34. Order the following species according to **increasing acid dissociation constant**, K_a:

CH_3COOH, CF_3COOH, CH_2FCOOH, CH_3CH_2OH

.

A) $CH_3COOH < CF_3COOH < CH_2FCOOH < CH_3CH_2OH$
B) $CF_3COOH < CH_2FCOOH < CH_3CH_2OH < CH_3COOH$
C) $CH_3CH_2OH < CF_3COOH < CH_2FCOOH < CH_3COOH$
D) $CH_3COOH < CH_2FCOOH < CF_3COOH < CH_3CH_2OH$
E) $CH_3CH_2OH < CH_3COOH < CH_2FCOOH < CF_3COOH$

35. In the experiment "Determination of an Equilibrium Constant for a Chemical Reaction" a calibration curve is generated to relate absorbance to $[FeSCN^{2+}]$. In preparing the calibration curve, $[FeSCN^{2+}]$ is assumed to be equal to $[SCN^-]_{initial}$, since $[Fe^{3+}]_{initial}$ is much greater than $[SCN^-]_{initial}$ for the calibration curve portion of the experiment. The equilibrium constant, *K*, for this reaction is 125. If 49 ml of 0.200 M Fe^{3+} is mixed with 1.0 ml of 0.00200 M SCN^-, what is the **percent error in $[FeSCN^{2+}]_{equilibrium}$** that results from this approximation?

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

.

A) 1.9%
B) 4.1%
C) 2.6%
D) 0.22%
E) 11%

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Some general data/formulas are provided on this page.

A Periodic Table with atomic weights is provided on the next page.

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

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

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

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

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

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

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

density(H_2O, l) = 1.00g/mL

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

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

1 atm = 101.325 kPa = 760 mm Hg

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 = 10^9 nm = 10^{10} Å

1 g = 10^3 mg

De Broglie wavelength:

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

Hydrogen atom energy levels:

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

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

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

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

Gibbs free energy of reaction: $\Delta G = \Delta G^{\circ} + RT\ln Q$

The roots of quadratic equation, $a\,x^2 + b\,x + c = 0$, are given by $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

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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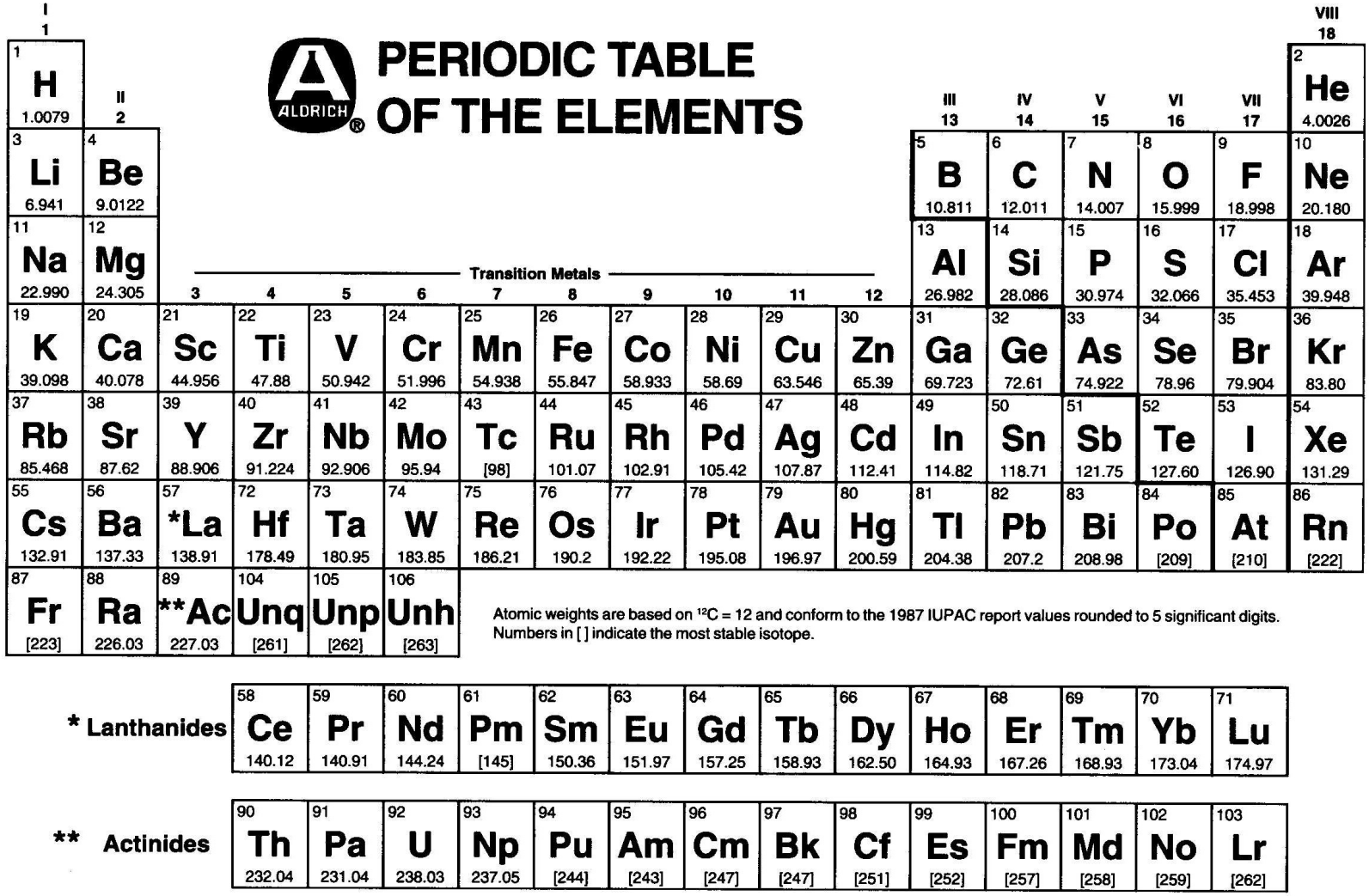

End of Exam