UNIVERSITY OF TORONTO
FACULTY OF ARTS AND SCIENCE

APRIL EXAMINATIONS 2014
CHM 139H1 S

Name (print): _____

Student No: _____ Tutorial Section: _____

DURATION: 3 HOURS **TOTAL MARKS = 85**

Calculators may be used but not shared. Programmable calculators may not be used. A **PERIODIC TABLE** and **USEFUL DATA** are attached to the back of the exam.

WHEN YOU RECEIVE YOUR EXAM PAPER AND COMPUTER ANSWER SHEET:

1. Write your name, student number and tutorial section on this page.
2. On the computer answer sheet:
   a) Write your last name, your given name, and signature at the **front** (top left corner) and at the **back** (top) of the sheet.
   b) **Blacken** the appropriate circles for your last name and initials.
   c) **Write** your student number along the top of the student number box and **blacken** the circles which correspond to your student number.

YOUR ANSWERS ARE TO BE RECORDED ON THE COMPUTER ANSWER SHEET AND ON THIS PAPER, BOTH OF WHICH MUST BE HANDED IN AT THE END OF THE EXAM.

Part A (30 × 1.5 = 45 marks)

1. Clearly circle on the test paper the letter (a, b, c, d, or e) for the best answer you choose for each question.
2. Blacken the circle (below a, b, c, d, or e) on the computer sheet which corresponds to the answer you have chosen for each question. Make sure that only one answer is blackened.
3. Use soft pencil (No. 2 or softer). Do not use ink or ball point pen.
4. The computer sheet must be filled during the time allotted for the test.

Part B (4 questions = 40 marks) Clearly and concisely showing your work is essential in order to receive full marks.

AT THE END OF THE EXAM: Insert your computer answer sheet into your exam paper. Remain seated until all exam papers have been collected.

MULTIPLE CHOICE QUESTIONS (1.5 marks each)

1. Phosphine, an extremely poisonous and highly reactive gas, will react with oxygen to form tetraphosphorus decaoxide and water. Calculate the mass of $P_4O_{10}(s)$ formed when 225 g of PH_3 reacts with excess oxygen.

$$PH_3(g) + O_2(g) \rightarrow P_4O_{10}(s) + H_2O(g) \quad \textbf{[unbalanced]}$$

a) 1880 g
b) 940 g
c) 900 g
d) 470 g
e) 56.3 g

2. The shape of an atomic orbital is associated with:

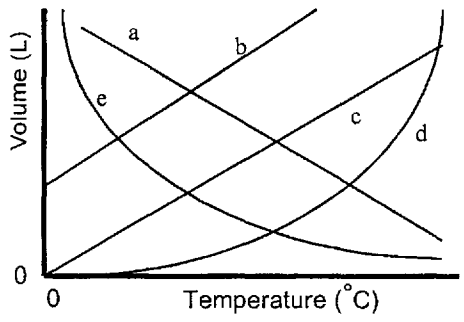
a) The principle quantum number (n)
b) The angular momentum quantum number (l)
c) The magnetic quantum number (m_l)
d) The spin quantum number (m_s)
e) The magnetic (m_l) and spin (m_s) quantum numbers, together

3. A gas mixture, with a total pressure of 300 torr, consists of equal masses of Ne and Ar. What is the partial pressure of Ar, in torr?

a) 75.0 torr
b) 150 torr
c) 100 torr
d) 300 torr
e) None of the above

4. Which of the lines on the figure below is the best representation of the relationship between the volume of an ideal gas and its temperature in Celsius, other factors remaining constant?

a) Line a
b) Line b
c) Line c
d) Line d
e) Line e



5. Which of the following is an ionic compound?

   a) H_2S
   b) NH_3
   c) I_2
   d) KI
   e) CCl_4

6. A 1.00 L saturated solution of carbon dioxide in water contains 3.00 g of $CO_2(aq)$ when the $CO_2(g)$ partial pressure is 8.0 atm. If the partial pressure of CO_2 is decreased to 3.2 atm, how many grams of CO_2 ***will remain*** in the aqueous phase?

   a) 0.90 g
   b) 1.60 g
   c) 1.40 g
   d) 1.20 g
   e) 2.20 g

7. An aqueous solution of sucrose, $C_{12}H_{22}O_{11}$, has a freezing point of –3.125°C. What is the concentration of sucrose in the solution? (K_f (H_2O) = 1.858 °C /*m*)

   a) 1.56 *m*
   b) 1.75 *m*
   c) 1.68 *m*
   d) 0.145 *m*
   e) 14.7 *m*

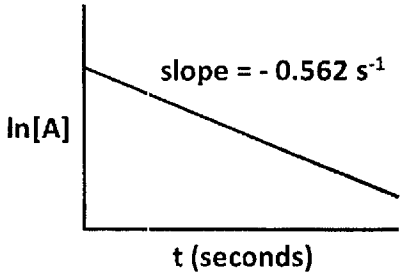
8. The vapor pressure of pure toluene is 400 torr and that of pure 1,2-dimethylbenzene is 150 torr at 90°C. These two solutions are mixed at 90 °C such that the total vapour pressure of the solution is 380 torr. What is the mole fraction of toluene and 1,2-dimethylbenzene in the solution phase? Assume ideal solution behavior.

   a) 0.32 toluene; 0.68 1,2-dimethylbenzene
   b) 0.46 toluene; 0.54 1,2-dimethylbenzene
   c) 0.87 toluene; 0.13 1,2-dimethylbenzene
   d) 0.98 toluene; 0.02 1,2-dimethylbenzene
   e) 0.92 toluene; 0.08 1,2-dimethylbenzene

9. The rate constant for a reaction is 5.67×10^{-6} L mol^{-1} s^{-1}. What is the overall order of the reaction?

   a) Zero
   b) First
   c) Second
   d) Third
   e) Not enough information given

10. Given the plot on the left, what is the half-life of compound A?



   a) 6.57 seconds
   b) 1.78 seconds
   c) 1.23 seconds
   d) 8.12 seconds
   e) Half-life depends on the initial concentration

11. 0.80 M of A is present ***after*** the reaction has proceeded for 4.5 seconds. Using information from the plot on the left, calculate the initial concentration of A.

   a) 10 M
   b) 150 M
   c) 25 M
   d) 48 M
   e) 8.2 M

12. The elementary reaction between NO and HO_2 shown below has an activation energy of 0.80 kJ in the forward direction, given the enthalpy change of this reaction, what is the activation energy of the reaction in the ***reverse direction***?

$$NO + HO_2 \rightarrow NO_2 + OH \qquad \Delta H = -1.3 \text{ kJ}$$

   a) 2.1 kJ mol^{-1}
   b) 6.5 kJ mol^{-1}
   c) 0.52 kJ mol^{-1}
   d) 1.3 kJ mol^{-1}
   e) 0.048 kJ mol^{-1}

13. You have a solution of nitrous acid (HNO_2, $K_a = 4.5 \times 10^{-4}$) that is pH 2.34. If you add solid potassium nitrite (KNO_2) to this solution, what will happen?

a) The pH will not change
b) The pH will increase
c) The pH will decrease
d) The pKa will increase
e) The pKa will decrease

14. Which is the best acid to use in the preparation of a buffer with pH = 3.3?

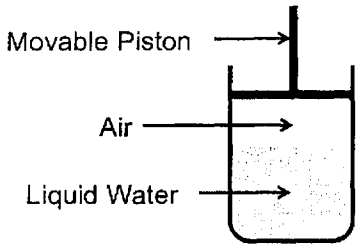
a) HOI ($K_a = 2.0 \times 10^{-11}$)
b) HNO_2 ($K_a = 4.5 \times 10^{-4}$)
c) HNO_3
d) HOI_3 ($K_a = 1.7 \times 10^{-1}$)
e) H_2CO_3 ($K_a = 4.3 \times 10^{-7}$)

15. For the reaction between nitrogen (N_2) and oxygen (O_2) to produce nitrogen dioxide (NO_2), what is the concentration of N_2 at equilibrium when the equilibrium concentration of NO_2 is five times (5x) the equilibrium concentration of O_2?

$$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g) \qquad K_c = 8.3 \times 10^{-10}$$

a) 3.3×10^{-11} M
b) 1.7×10^{-10} M
c) 6.0×10^{9} M
d) 3.0×10^{10} M
e) 1.7×10^{10} M

16. A vessel with a movable piston is partially filled with liquid water. If you increase the volume of the vessel by moving the piston out what will happen?



$$H_2O(l) \rightarrow H_2O(g) \qquad \Delta H = 45.6 \text{ kJ mol}^{-1}$$

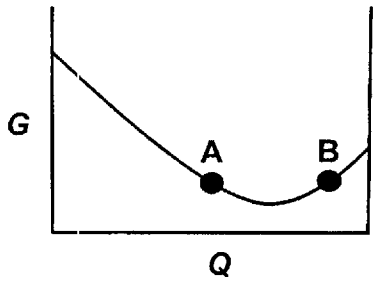
a) The mass of liquid water will decrease
b) The temperature of the liquid water will decrease
c) The number of moles of gas phase water will increase
d) The system will adjust to reestablish equilibrium
e) (a) to (d) are all true

17. All of the following are state functions ***with the exception of:***

a) Internal energy
b) Volume
c) Work
d) Pressure
e) Enthalpy

18. Which one of the following is the correct format of a formation reaction?

a) C (*diamond*) → C (*graphite*)
b) H_2 (*g*) + O (*g*) → H_2O (*l*)
c) C (*graphite*) + 4H (*g*) → CH_4 (*g*)
d) 6C (*graphite*) + 6H_2O (*s*) → $C_6H_{12}O_6$ (*s*)
e) 2C (*graphite*) + 3H_2(*g*) + ½O_2(*g*) → C_2H_5OH(*l*)



19. All of the following statements are true with respect to the *G vs. Q* plot on the left ***with the exception of:***

a) At equilibrium the system is at an energetic minimum
b) Q = 1 at standard state
c) At point A the reaction will be spontaneous in the forward direction, and at point B the reaction will be spontaneous in the reverse direction
d) At equilibrium Q = K
e) At point A Q > K, and at point B Q < K

20. The standard molar entropy of bromine gas ($Br_2(g)$) is 245.46 J mol^{-1} K^{-1} at 25 °C. Given that ΔS° is 104.58 J mol^{-1} K^{-1} for the dissociation of one mole of $Br_2(g)$ into bromine atoms (Br(*g*)), what is the standard molar entropy for Br(*g*) at 25 °C?

a) 70.44 J mol^{-1} K^{-1}
b) 140.08 J mol^{-1} K^{-1}
c) 175.02 J mol^{-1} K^{-1}
d) 350.04 J mol^{-1} K^{-1}
e) 158.12 J mol^{-1} K^{-1}

21. Which of the following statements appropriately describes the thermodynamics of the reaction of solid boron (B) and chlorine gas (Cl_2) to produce boron trichloride (BCl_3)?

$$B(s) + \frac{3}{2}Cl_2(g) \rightleftharpoons BCl_3(g)$$

ΔG_f°			-338.7 kJ mol^{-1}
ΔH_f°			-403.8 kJ mol^{-1}
S_f°	5.9 J mol^{-1} K^{-1}	223 J mol^{-1} K^{-1}	290.0 J mol^{-1} K^{-1}

a) The reaction is spontaneous at all temperatures
b) The reaction is non-spontaneous at all temperatures
c) The reaction is spontaneous at higher temperatures
d) The reaction is spontaneous at lower temperatures
e) The spontaneity of the reaction is independent of temperature

22. The enthalpy and equilibrium constant for the reaction between NO and Cl_2 to produce NOCl are given below. If 1.0 mol of all three species are mixed in a 1.0 L container, which of the following statements is ***true***?

$$2NO + Cl_2 \rightleftharpoons 2NOCl \quad \Delta H = -77 \text{ kJ}, \quad K_C = 4.0 \times 10^{10}$$

a) Cl_2 is the limiting reagent
b) NOCl is the limiting reagent
c) There would be no net reaction as the system is already at equilibrium
d) 39 kJ of heat energy would be released in the resulting reaction
e) 77 kJ of heat energy would be released in the resulting reaction

23. Calculate $\Delta G°$ for the reaction between chromium (Cr^{3+}) and mercury (Hg).

$$2Cr^{3+}(aq) + 6Hg(l) \rightarrow 2Cr(s) + 3Hg_2^{2+}(aq) \qquad E^\circ = 1.59 \text{ V}$$

a) –920 kJ
b) –767 kJ
c) –460 kJ
d) –307 kJ
e) –540 kJ

24. A battery is considered "dead" when

a) $Q < 1$
b) $Q = 1$
c) $Q > 1$
d) $Q = K$
e) $Q/K = 0$

25. All of the following are redox reactions ***with the exception of:***

a) $Al(OH)_4^-(aq) + 4H^+(aq) \rightarrow Al^{3+}(aq) + 4H_2O(l)$
b) $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$
c) $Na_6FeCl_8(s) + 2Na(l) \rightarrow 8NaCl(s) + Fe(s)$
d) $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$
e) $CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$

26. What mass of copper will be formed when a constant current of 30.0 A is passed through molten copper (I) bromide (CuBr) for 1.50 hours?

a) 241 g
b) 54.0 g
c) 107 g
d) 10.7 g
e) 364 g

27. Calculate the value of the cell potential (E_{cell}) for the galvanic cell expressed using the shorthand notation below at 25 °C.

$$Zn(s) \mid Zn^{2+}(aq, 0.0100\ M) \mid\mid Aq^{+}(aq, 1.25\ M) \mid Ag(s)$$

a) 1.62
b) 0.87
c) 1.57
d) 1.76
e) 1.32

28. A sacrificial anode is a metal that is easily oxidized and as such protects other metals from being oxidized themselves. Would any of metals listed below be capable of acting as a sacrificial anode for an iron surface?

$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$ $\quad E^\circ = -0.44$ V

a) copper: $Cu^{2+} + 2e^- \rightarrow Cu$ $\quad E^\circ = 0.15$ V
b) cobalt: $Co^{2+} + 2e^- \rightarrow Co$ $\quad E^\circ = -0.28$ V
c) chromium: $Cr^{2+} + 2e^- \rightarrow Cr$ $\quad E^\circ = -0.74$ V
d) tin: $Sn^{2+} + 2e^- \rightarrow Sn$ $\quad E^\circ = -0.14$ V
e) nickel: $Ni^{2+} + 2e^- \rightarrow Ni$ $\quad E^\circ = -0.26$ V

29. As a redox reaction proceeds spontaneously in the forward direction, which ***one*** of the following statements ***must be true***?

a) ΔG, E_{cell}, and K all decreasing
b) ΔG, E_{cell}, and K all increasing
c) ΔG and E_{cell} both tend to zero
d) ΔG, ΔH, ΔS are all negative
e) ΔG and ΔH are negative, and ΔS is positive

30. Use the reduction half-cell potentials below to calculate the solubility product constant (K_{sp}) for silver chloride (AgCl) at 25 °C.

$AgCl(s) + e^- \rightarrow Ag(s) + Cl^-(aq)$ $\quad E^\circ = 0.22$ V
$Ag^+(aq) + e^- \rightarrow Ag(s)$ $\quad E^\circ = 0.80$ V

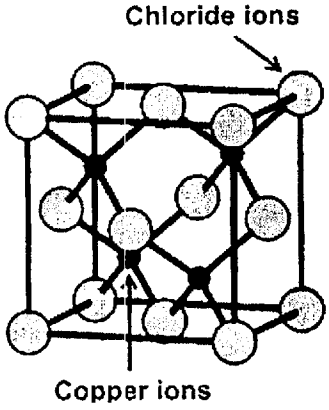
a) 8.55×10^{-5}
b) 7.15×10^{-25}
c) 5.65×10^{-12}
d) 5.66×10^{-7}
e) 1.55×10^{-10}

Name: _____ Student Number: _____ Tutorial: T_____

PG1:	/10
PG2:	/10
PG3:	/10
PG4:	/10
Total:	/40

SHORT ANSWER QUESTIONS: Be sure to show your work.

1. **(7 marks)** ***Exactly one unit cell*** of a crystal of CuCl is depicted below.
(copper ions are dark and small, while chloride ions are light and larger)



(a) What kind of packing do the chloride ions adopt? **(2 marks)**

(b) How many copper and how many chloride ions are in each unit cell? **(1 mark)**

Copper ions:

Chloride ions:

(c) If CuCl has a density of 4.145 g/cm^3, what is the cell edge length of the cubic cell of CuCl depicted in the diagram above? (MW CuCl is 98.999 g/mol) **(4 marks)**

2. **(3 marks)** Two aqueous solutions are prepared: solution A (1.00 *m* Na_2SO_4) and solution B (1.00 *m* NaCl). Circle the correct answers below.

(a) If the two solutions, A and B, are separated by a semipermeable membrane. The osmotic pressure of which solution would immediately begin to decrease?

Solution A Solution B

(b) The solvent molecules are moving:

From solution A to solution B From solution B to solution A

(c) If, because of evaporation, the volumes of both solutions decrease by the same amount, how will the osmotic pressure of the aqueous solutions change?

Increase no change decrease

3. **(6 marks)** Hydrogen peroxide ($H_2O_2(aq)$) reacts with copper metal ($Cu(s)$) to produce copper ions ($Cu^{2+}(aq)$) and hydroxide ions ($OH^-(aq)$): $H_2O_2(aq) + Cu(s) \rightarrow Cu^{2+}(aq) + 2OH^-(aq)$

(a) The rate constant for this reaction in the forward direction is 1.40 M^{-1} s^{-1} at 25.0 °C and 5.75 M^{-1} s^{-1} at 50.0 °C. What is the activation energy for this reaction in the forward direction? **(2 marks)**

(b) What is the rate constant for this reaction in the forward direction at 90 °C? **(2 marks)**

(c) To push the equilibrium to the right, increasing the equilibrium concentration of copper ions (Cu^{2+}), should the reaction be carried out in an acidic or a basic buffer? Explain your answer. **(2 marks)**

4. **(4 marks)** The rearrangement reaction of $HONO(g)$ to $HNO_2(g)$ ($HONO(g) \rightleftharpoons HNO_2(g)$) has a K_p value of 0.47.

(a) 0.89 atm of HONO is added to an evacuated cylinder. Calculate the equilibrium partial pressure HNO_2 after the system is allowed to establish equilibrium. **(2 marks)**

(b) What is the total pressure of the system at equilibrium? **(2 marks)**

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5. **(4 marks)** The reaction between sodium hydroxide (NaOH) and sulfuric acid (H_2SO_4) was studied in a coffee cup calorimeter. 100 mL of 1.00 M NaOH and 100 mL of 1.00 M H_2SO_4, each at 24.0°C, were mixed. After mixing the maximum temperature of the solution was 30.6°C. Answer the following questions, assuming the heat capacity of the cup and the thermometer are negligible, and that all solutions have a density of exactly 1.0 g/mL.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(a) Calculate the total heat energy generated during this reaction. **(2 marks)**

(b) Calculate the enthalpy of the reaction ΔH, in kJ/mol of Na_2SO_4 produced. **(2 marks)**

6. **(6 marks)** Consider the phase transition from ice to liquid water ($H_2O(s) \rightarrow H_2O(l)$) at 1.0 atm and 0 °C (the melting point of ice) in a closed container. Under these conditions predict whether each of the following quantities will be greater than, less than, or equal to zero (i.e., > 0, < 0, or = 0). Explain each prediction in one sentence.

i) $\Delta H°$ [ ] 0

ii) $\Delta S°$ [ ] 0

iii) $\Delta G°$ [ ] 0

7. **(10 marks)** Answer the following questions using the half-cell potentials below.

$Mn^{3+}(aq) + e^- \rightarrow Mn^{2+}(aq)$ $\quad E^\circ = 1.54\ V$

$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$ $\quad E^\circ = 1.81\ V$

(a) What is the E_{cell} of the electrochemical cell between manganese (Mn^{3+}/Mn^{2+}) and cobalt (Co^{3+}/Co^{2+}) that would be spontaneous in the forward direction when all aqueous concentrations are 1.0 M? **(2 marks)**

(b) Sodium carbonate (Na_2CO_3) is added to the manganese half-cell in part (a), which results in the formation of a $MnCO_3$ precipitate. Assuming no change in volume, what is the resulting concentration of manganese (II) ions (Mn^{2+}) if the final equilibrium concentration of carbonate ions (CO_3^{2-}) is 0.010 M? ($K_{sp}(MnCO_3) = 2.2 \times 10^{-11}$) **(3 marks)**

(c) What is the E_{cell} of the electrochemical cell after the addition of carbonate described in part (b)? (Assume no interaction between carbonate (CO_3^{2-}) and manganese (III) ions (Mn^{3+})) **(3 marks)**

(d) Which electrochemical half-cell will act as the anode in the electrochemical cells described in part (a) and part (c)? Explain why the anode is different or why it is the same. **(2 marks)**

anode part (a):

anode part (c):

USEFUL EQUATIONS

$$E = h\nu \qquad c = \lambda\nu \qquad E_n = \frac{-2.18\times10^{-18}J}{n^2} \quad n = 1,2,3,...$$

$$PV = nRT \qquad E_{kin} = \frac{3}{2}RT \qquad u = \left(\frac{3RT}{M}\right)^{\frac{1}{2}} \qquad \ln\left(\frac{P_2}{P}\right) = -\frac{\Delta H}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$P_A = X_A P_A^o \qquad \Delta T_b = K_b c_m$$

$$\text{solubility} = k \cdot P \qquad \left(P + \frac{an^2}{V^2}\right)\left(V - nb\right) = nRT$$

$$\Pi = MRT \qquad \Delta T_f = K_f c_m$$

$$\ln k = \ln A - \frac{E_a}{RT} \qquad \ln\left(\frac{[A]}{[A]_0}\right) = -kt \qquad \frac{1}{[A]} - \frac{1}{[A]_0} = kt$$

$$\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \qquad t_{\frac{1}{2}} = \frac{\ln(2)}{k} \qquad t_{\frac{1}{2}} = \frac{1}{k[A]_o}$$

$$K_p = K_c(RT)^{\Delta n} \qquad pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right) \qquad V = \frac{4}{3}\pi r^3$$

$$\Delta G = \Delta H - T\Delta S \qquad \Delta G^\circ = -RT\ln(K) \qquad \Delta G = \Delta G^o + RT\ln Q$$

$$q = C\Delta Tm \qquad w = -P\Delta V \qquad \Delta E = q + w$$

$$E^\circ = \frac{RT}{nF}\ln(K) \qquad E_{cell} = E^o_{cell} - \frac{RT}{nF}\ln Q \qquad \Delta G = -nFE_{cell}$$

$$For \quad ax^2 + bx + c = 0, \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

PHYSICAL AND CHEMICAL CONSTANTS

Atomic mass unit	1 a.m.u. = $1.6605402 \times 10^{-27}$ kg
Mass of an electron	$m_e = 9.109 \times 10^{-31}$ kg
Mass of a neutron	$m_n = 1.674 \times 10^{-27}$ kg
Mass of a proton	$m_p = 1.672 \times 10^{-27}$ kg
Avogadro's number	$N_A = 6.0221367 \times 10^{23}$ mol^{-1}
Boltzmann's constant	$k = 1.380658 \times 10^{-23}$ J K^{-1}
Faraday's constant	$F = 9.6485309 \times 10^{4}$ C mol^{-1}
Fundamental unit charge	$e = 1.60217733 \times 10^{-19}$ C
Gas constant	$R = 8.314510$ J mole^{-1} K^{-1}
	$= 0.082058$ L atm mol^{-1} K^{-1}
Heat capacity of water	$C = 4.184$ J g^{-1} K^{-1}
	$= 75.4$ J mole^{-1} K^{-1}
Planck's constant	$h = 6.6260755 \times 10^{-34}$ J s
Rydberg's constant	$R_H = 2.1798 \times 10^{-18}$ J
	$= 1.097 \times 10^{-2}$ nm^{-1}
Speed of light	$c = 2.99792458 \times 10^{8}$ m s^{-1}
Zero point	0°C = 273.15 K
K_w of H_2O at 25°C	$K_w = 1.00 \times 10^{-14}$
Pi	$\pi = 3.1415927$

CONVERSION FACTORS

1 atmosphere (atm) = 1.01325×10^5 Pa = 760.0 mm Hg (torr) = 1.01325 bar

1m = 10 dm = 10^2 cm = 10^3 mm = 10^6 μm = 10^9 nm = 10^{12} pm

1 L = 1 dm^3

1 L atm = 101.325 J = 24.217 cal

1 calorie (cal) = 4.184 joules (J)

1 debye (D) = 3.335617×10^{-30} C m

1 eV/particle = 96.485 kJ mole^{-1} = 23.061 kcal mole^{-1}

1 eV = 1.602×10^{-19} J = 8067 cm^{-1}

1 V = 1 J/C

1 A = 1 C/s

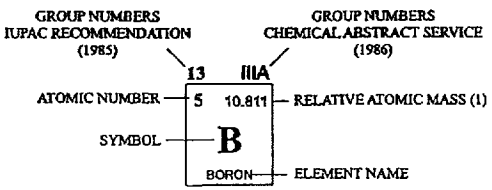
1 kcal mole^{-1} = 4.184 kJ mole^{-1} = 349.73 cm^{-1}

1 kJ mole^{-1} = 0.23901 kcal mole^{-1} = 83.591 cm^{-1}

ln x = 2.3026 log x

PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/



PERIOD	GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 **H** HYDROGEN																	2 4.0026 **He** HELIUM
2	3 6.941 **Li** LITHIUM	4 9.0122 **Be** BERYLLIUM											5 10.811 **B** BORON	6 12.011 **C** CARBON	7 14.007 **N** NITROGEN	8 15.999 **O** OXYGEN	9 18.998 **F** FLUORINE	10 20.180 **Ne** NEON
3	11 22.990 **Na** SODIUM	12 24.305 **Mg** MAGNESIUM											13 26.982 **Al** ALUMINIUM	14 28.086 **Si** SILICON	15 30.974 **P** PHOSPHORUS	16 32.065 **S** SULPHUR	17 35.453 **Cl** CHLORINE	18 39.948 **Ar** ARGON
4	19 39.098 **K** POTASSIUM	20 40.078 **Ca** CALCIUM	21 44.956 **Sc** SCANDIUM	22 47.867 **Ti** TITANIUM	23 50.942 **V** VANADIUM	24 51.996 **Cr** CHROMIUM	25 54.938 **Mn** MANGANESE	26 55.845 **Fe** IRON	27 58.933 **Co** COBALT	28 58.693 **Ni** NICKEL	29 63.546 **Cu** COPPER	30 65.39 **Zn** ZINC	31 69.723 **Ga** GALLIUM	32 72.64 **Ge** GERMANIUM	33 74.922 **As** ARSENIC	34 78.96 **Se** SELENIUM	35 79.904 **Br** BROMINE	36 83.80 **Kr** KRYPTON
5	37 85.468 **Rb** RUBIDIUM	38 87.62 **Sr** STRONTIUM	39 88.906 **Y** YTTRIUM	40 91.224 **Zr** ZIRCONIUM	41 92.906 **Nb** NIOBIUM	42 95.94 **Mo** MOLYBDENUM	43 (98) **Tc** TECHNETIUM	44 101.07 **Ru** RUTHENIUM	45 102.91 **Rh** RHODIUM	46 106.42 **Pd** PALLADIUM	47 107.87 **Ag** SILVER	48 112.41 **Cd** CADMIUM	49 114.82 **In** INDIUM	50 118.71 **Sn** TIN	51 121.76 **Sb** ANTIMONY	52 127.60 **Te** TELLURIUM	53 126.90 **I** IODINE	54 131.29 **Xe** XENON
6	55 132.91 **Cs** CAESIUM	56 137.33 **Ba** BARIUM	57-71 **La-Lu** Lanthanide	72 178.49 **Hf** HAFNIUM	73 180.95 **Ta** TANTALUM	74 183.84 **W** TUNGSTEN	75 186.21 **Re** RHENIUM	76 190.23 **Os** OSMIUM	77 192.22 **Ir** IRIDIUM	78 195.08 **Pt** PLATINUM	79 196.97 **Au** GOLD	80 200.59 **Hg** MERCURY	81 204.38 **Tl** THALLIUM	82 207.2 **Pb** LEAD	83 208.98 **Bi** BISMUTH	84 (209) **Po** POLONIUM	85 (210) **At** ASTATINE	86 (222) **Rn** RADON
7	87 (223) **Fr** FRANCIUM	88 (226) **Ra** RADIUM	89-103 **Ac-Lr** Actinide	104 (261) **Rf** RUTHERFORDIUM	105 (262) **Db** DUBNIUM	106 (266) **Sg** SEABORGIUM	107 (264) **Bh** BOHRIUM	108 (277) **Hs** HASSIUM	109 (268) **Mt** MEITNERIUM	110 (281) **Uun** UNUNNILIUM	111 (272) **Uuu** UNUNUNIUM	112 (285) **Uub** UNUNBIUM		114 (289) **Uuq** UNUNQUADIUM				

LANTHANIDE 6	57 138.91 **La** LANTHANUM	58 140.12 **Ce** CERIUM	59 140.91 **Pr** PRASEODYMIUM	60 144.24 **Nd** NEODYMIUM	61 (145) **Pm** PROMETHIUM	62 150.36 **Sm** SAMARIUM	63 151.96 **Eu** EUROPIUM	64 157.25 **Gd** GADOLINIUM	65 158.93 **Tb** TERBIUM	66 162.50 **Dy** DYSPROSIUM	67 164.93 **Ho** HOLMIUM	68 167.26 **Er** ERBIUM	69 168.93 **Tm** THULIUM	70 173.04 **Yb** YTTERBIUM	71 174.97 **Lu** LUTETIUM
ACTINIDE 7	89 (227) **Ac** ACTINIUM	90 232.04 **Th** THORIUM	91 231.04 **Pa** PROTACTINIUM	92 238.03 **U** URANIUM	93 (237) **Np** NEPTUNIUM	94 (244) **Pu** PLUTONIUM	95 (243) **Am** AMERICIUM	96 (247) **Cm** CURIUM	97 (247) **Bk** BERKELIUM	98 (251) **Cf** CALIFORNIUM	99 (252) **Es** EINSTEINIUM	100 (257) **Fm** FERMIUM	101 (258) **Md** MENDELEVIUM	102 (259) **No** NOBELIUM	103 (262) **Lr** LAWRENCIUM

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Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

Editor: Aditya Vardhan (adivar@nettlinx.com)

Standard Reduction Potentials (in Volts), 25°C

Reaction	E°(V)
$Cl_2 + 2e^-$ $2Cl^-$	+1.36
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.23
$Br_2 + 2e^- \rightarrow 2Br^-$	+1.07
$Fe^{3+} + e^- \text{---> } Fe^{2+}$	+0.77
$Ag^+ + e^- \text{---> } Ag$	+0.80
$I_2 + 2e^- \text{---> } 2I^-$	+0.54
$Cu^+ + e^- \text{---> } Cu$	+0.52
$Fe(CN)_6^{3-} + e^- \text{---> } Fe(CN)_6^{4-}$	+0.36
$Cu^{2+} + 2e^- \text{---> } Cu$	+0.34
$Cu^{2+} + e^- \text{---> } Cu^+$	+0.15
$Sn^{4+} + 2e^- \text{---> } Sn^{2+}$	+0.15
$2H^+ + 2e^- \text{---> } H_2$	0.00
$Fe^{3+} + 3e^- \text{---> } Fe$	-0.04
$Pb^{2+} + 2e^- \text{---> } Pb$	-0.13
$Ni^{2+} + 2e^- \text{---> } Ni$	-0.26
$Fe^{2+} + 2e^- \text{---> } Fe$	-0.41
$Cr^{3+} + 3e^- \text{---> } Cr$	-0.74
$Zn^{2+} + 2e^- \text{---> } Zn$	-0.76
$2H_2O + 2e^- \text{---> } H_2(g) + 2OH^-$	-0.83
$V^{2+} + 2e^- \text{---> } V$	-1.18
$Mn^{2+} + 2e^- \text{---> } Mn$	-1.18
$Al^{3+} + 3e^- \text{---> } Al$	-1.66
$Mg^{2+} + 2e^- \text{---> } Mg$	-2.37