UNIVERSITY OF TORONTO
FACULTY OF ARTS AND SCIENCE

APRIL EXAMINATIONS 2013
CHM 139H1 S

Name (print): _____

Student No: _____ Tutorial Section: _____

DURATION: 3 HOURS **TOTAL MARKS = 89**

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 = 44 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.

QUESTION (PART B)	MARK
1	/10
2	/10
3	/12
4	/12
TOTAL (PART B)	/ 44

TOTAL (PART A) = _____/45 **EXAM TOTAL = _____/ 89**

PART A: MULTIPLE CHOICE QUESTIONS

1. What is the chemical symbol for an atom that has 29 protons and 36 neutrons?

   a) P
   b) Kr
   c) Cu
   d) Tb
   e) Zn

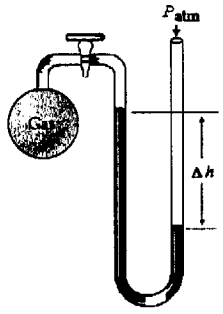
2. How many moles of BCl_3 are needed to produce 25.0 g of HCl(*aq*) in the following reaction?

$$BCl_3\,(g) + 3\,H_2O(l) \longrightarrow 3\,HCl(aq) + B(OH)_3\,(aq)$$

   a) 0.229 mol
   b) 0.686 mol
   c) 2.06 mol
   d) 3.00 mol
   e) 4.38 mol

3. What is the pressure (in mm Hg) of the gas inside the apparatus (shown below) if the outside pressure, P_{atm}, is 750 mm Hg and the difference in mercury levels, Δh, is 50 mm Hg?

   a) 50 mm Hg
   b) 700 mm Hg
   c) 750 mm Hg
   d) 800 mm Hg
   e) 850 mm Hg



4. A 4.00-L flask contains gas A at 25°C and 1 atm pressure. When the temperature is increased to 100°C, gas A decomposes completely according to the following reaction: A(g) → 2B (g) + C (g) What is the final pressure in the flask?

   a) 1.25 atm
   b) 2.60 atm
   c) 3.00 atm
   d) 3.76 atm
   e) 4.22 atm

5. For an electron in a given atom, the larger *n* (the value of the principle quantum number), the

   a) larger its average distance from the nucleus and the higher its orbital energy
   b) larger its average distance from the nucleus and the lower its orbital energy
   c) smaller its average distance from the nucleus and the higher its orbital energy
   d) smaller its average distance from the nucleus and the lower its orbital energy
   e) larger its average distance from the nucleus, whereas the energy stays the same

6. Identify the excited state electron configuration for a neutral fluorine atom.

   a) $1s^2 2s^2 2p^5$
   b) $1s^2 2s^2 2p^6$
   c) $1s^2 2s^2 2p^4$
   d) $1s^2 2s^2 2p^4 3s^1$
   e) $1s^1 2s^3 2p^5$

7. For potassium metal, the binding energy E_b (the minimum energy needed to eject an electron from the metal surface) is 3.68×10^{-19} J. How many photons having a 700 nm wavelength will be required to eject an electron?

   a) 1
   b) 2
   c) 3
   d) 4
   e) None of the above

8. Which of the following lists the substances in order of increasing melting points?

   a) $C_4H_{10} < He < MgO < HF$
   b) $C_4H_{10} < He < HF < MgO$
   c) $He < C_4H_{10} < HF < MgO$
   d) $HF < C_4H_{10} < He < MgO$
   e) $He < HF < C_4H_{10} < MgO$

9. The rate of appearance of Br_2 is 6.5 M s^{-1}, what is the rate of disappearance of BrCl

$$BrCl \rightarrow \tfrac{1}{2}Br_2 + \tfrac{1}{2}Cl_2$$

   a) 13 M s^{-1}
   b) 6.5 M s^{-1}
   c) 10 M s^{-1}
   d) 3.3 M s^{-1}
   e) 5.0 M s^{-1}

10. A catalyst decreases the activation energy of a reaction by 6.8 kJ/mol. What is the subsequent increase in the rate of the reaction at 25 °C? (Assume the frequency factor (A) is unchanged)

a) rate is unchanged
b) 10 times faster
c) 1.4×10^4 times faster
d) 1.2 times faster
e) 16 times faster

11. A reactant R is being consumed in a first-order reaction. What fraction of the initial R is consumed in 4.0 half-lives?

a) 0.94
b) 0.87
c) 0.75
d) 0.13
e) 0.063

12. For the reaction between nitrogen dioxide and water, which of the disturbances described below would move the equilibrium towards the reactants?

$$3NO_2(g) + H_2O(l) \rightleftharpoons 2HNO_3(aq) + NO(g) \qquad \Delta H = -140 \text{ kJ/mol}$$

a) Decrease the volume of the container
b) Increase the pressure within the container by adding Ne(g)
c) Increase the temperature
d) Add a catalyst
e) Decrease the concentration of nitric acid (HNO_3)

13. Which set of acids is correctly ranked from weakest to strongest?

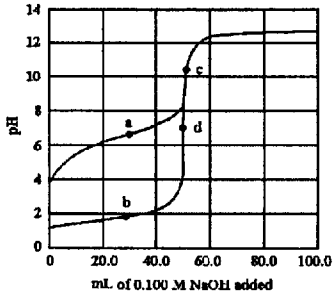
a) $HCl < HBr < HF < HI$
b) $H_2SO_4 < H_2SO_3$
c) $CH_4 < NH_3 < H_2O < HF$
d) $H_2S < H_2O$
e) None of them are in the correct order

14. What is the expected pH of a buffer formed from the addition of 0.30 moles of HCl to 0.65 moles of CH_3NH_2 (pK_b 3.36) in a total volume of 1.0 L.

a) 10.57
b) 11.20
c) 10.70
d) 3.30
e) 3.70

15. The following plot shows two titration curves, each representing the titration of 50.00 mL of 0.100 M acid with 0.100 M NaOH. Which point represents the equivalence point for the titration of a strong acid?

a) point a
b) point b
c) point c
d) point d
e) none of the points



16. The reaction between hydrogen and oxygen to give gaseous water has an equilibrium constant of 9.5×10^{40} at 25°C. Which of the statements below is true?

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons H_2O(g) \qquad \Delta H^\circ = -242 \text{ kJ/mol}$$

a) This reaction is spontaneous at all temperatures
b) This reaction is spontaneous at lower temperatures, but not spontaneous at higher temperatures
c) This reaction is spontaneous at higher temperatures, but not spontaneous at lower temperatures
d) This reaction is not spontaneous at any temperature
e) This reaction is at equilibrium

17. Galena is the ore from which elemental lead is extracted. In the first step of the extraction process, galena is reacted in air to form lead(II) oxide.

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g) \qquad \Delta H = -827.4 \text{ kJ}$$

What mass of galena is converted to lead oxide if 975 kJ of heat are liberated?

a) 203 g
b) 282 g
c) 406 g
d) 478 g
e) 564 g

18. Calculate the enthalpy change for the reaction: $NO(g) + O(g) \rightarrow NO_2(g)$ given the following data:

$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$ $\Delta H = -198.9$ kJ

$O_3(g) \rightarrow 3/2\ O_2(g)$ $\Delta H = -142.3$ kJ

$O_2(g) \rightarrow 2O(g)$ $\Delta H = 495.0$ kJ

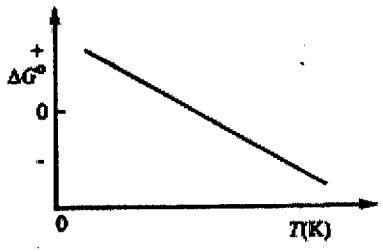
a) -551.6 kJ
b) -304.1 kJ
c) 190.9 kJ
d) 153.8 kJ
e) 438.4 kJ

19. Which of the following is always true for an endothermic process in which the system is closed and the pressure is constant?

a) $q_{sys} > 0$, $\Delta S_{surr} < 0$
b) $q_{sys} < 0$, $\Delta S_{surr} > 0$
c) $q_{sys} < 0$, $\Delta S_{surr} < 0$
d) $q_{sys} > 0$, $\Delta S_{surr} > 0$
e) $w < 0$

20. Consider the plot (shown below) of $\Delta G°$ versus temperature for a chemical reaction. Which of the following is ***incorrect***?

a) The reaction is spontaneous at some higher temperatures.



b) $\Delta S° < 0$

c) $\Delta H° > 0$

d) At a certain temperature, the reaction is at equilibrium under standard state conditions.

e) When this reaction proceeds, heat is absorbed from the surroundings.

21. $Ag^+(aq) + e^- \rightarrow Ag(s)$ $E° = +0.800$ V

$AgBr(s) + e^- \rightarrow Ag(s) + Br^-(aq)$ $E° = +0.071$ V

$Br_2(l) + 2\ e^- \rightarrow 2\ Br^-(aq)$ $E° = +1.066$ V

Use **some** of the data above to calculate K_{sp} at 25°C for AgBr.

a) 6.3×10^{-2}
b) 4.9×10^{-13}
c) 1.9×10^{-15}
d) 2.4×10^{-34}
e) 7.4×10^{-36}

22. A spontaneous reaction is defined as:

a) An exothermic reaction
b) An endothermic reaction
c) A reaction where the entropy of the system is increased
d) An exothermic reaction where the entropy of the system is increased
e) A reaction where the entropy of the universe is increased

23. The equilibrium constant for a reaction is 1.7×10^{-4} at 100°C and 4.6×10^{-2} at 600°C, which of the following statements is true?

a) The reaction is exothermic
b) The reaction proceeds spontaneously from reactants to products
c) The reaction is endothermic
d) The products contain more moles of gas than the reactants
e) $Q < K$

24. Consider the following reaction: $CuI(s) \rightleftharpoons Cu^+(aq) + I^-(aq)$. At equilibrium, the concentrations of the Cu^+ and I^- ions in solution are both equal to 1.03×10^{-6} M. What is $\Delta G°$ for the reaction?

a) -68 kJ
b) 68 kJ
c) -30 kJ
d) 30 kJ
e) 34 kJ

25. You add 0.100 moles of $CuNO_3$ to a 100 mL 1.00 M solution of $Fe(NO_3)_3$ in a "coffee cup" calorimeter. The resulting redox reaction is given below. The temperature of the water in the calorimeter increases from 22.2°C to 28.6°C. Calculate the change in enthalpy (ΔH) of this reaction. (Heat capacity of water is 4.18 J g^{-1} K^{-1}, assume the density of water is 1.00 g mL^{-1})

$$Fe^{3+} + Cu^+ \rightarrow Cu^{2+} + Fe^{2+}$$

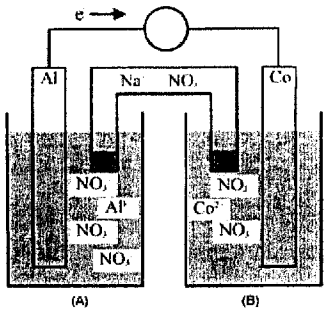
a) -2.68 kJ mol^{-1}
b) -26.8 J mol^{-1}
c) 50.1 kJ mol^{-1}
d) -50.1 kJ mol^{-1}
e) -26.8 kJ mol^{-1}

26. Which of the following statements is ***false*** with respect to the balanced redox reaction between copper and nitric acid? (Note: the reaction as shown is unbalanced)

$$Cu(s) + HNO_3(aq) \rightarrow Cu^{2+}(aq) + NO(g)$$

a) The reaction consumes H^+
b) The reaction consumes 3 moles of nitric acid (HNO_3)
c) The reaction produces water
d) The reaction produces 3 moles of copper ions (Cu^{2+})
e) This redox reaction results in a net transfer of 6 electrons for the balanced reaction with smallest whole number coefficients.

27. Consider the voltaic cell shown below. Identify the anode and cathode, and indicate the direction of Na^+ ion and NO_3^- ion flow from the salt bridge.



a) Al is the anode and Co is the cathode; Na^+ ions flow into half-cell compartment (A) and NO_3^- ions flow into half-cell compartment (B).
b) Al is the anode and Co is the cathode; NO_3^- ions flow into half-cell compartment (A) and Na^+ ions flow into half-cell compartment (B).
c) Co is the anode and Al is the cathode; Na^+ ions flow into half-cell compartment (A) and NO_3^- ions flow into half-cell compartment (B).
d) Co is the anode and Al is the cathode; NO_3^- ions flow into half-cell compartment (A) and Na^+ ions flow into half-cell compartment (B).
e) Co is the anode and Al is the cathode; there is not enough information to determine the direction of ion flow.

28. A solution is prepared by dissolving 32.0 g of $NiSO_4$ in water. What current would be needed to deposit all of the nickel metal in 5.0 hours?

a) 1.1 A
b) 2.2 A
c) 3.3 A
d) 4.4 A
e) 5.5 A

29. Consider the following half-reactions and E° values:

$Ag^{2+}(aq) + e^- \rightarrow Ag^+(aq)$ E° = 1.98 V
$Ag^+(aq) + e^- \rightarrow Ag(s)$ E° = 0.80 V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ E° = 0.34 V
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ E° = -0.13 V
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$ E° = -0.40 V

Which of the following is the strongest reducing agent?

a) Ag^+
b) Cd
c) Pb
d) Cu
e) Cd^{2+}

30. Consider the galvanic cell, $Pb(s)|\ Pb^{2+}(aq)||\ Cu^{2+}(aq)|\ Cu(s)$. Which one of the following changes to the cell would cause the cell potential to increase (i.e., become more positive)?

a) increase Pb^{2+} concentration
b) increase Cu^{2+} concentration
c) increase the mass of Pb(*s*)
d) decrease the mass of Pb(*s*)
e) none of the above

PART B. SHORT ANSWER QUESTIONS: Answers must be written in pen in the boxes provided. Be sure to show your work.

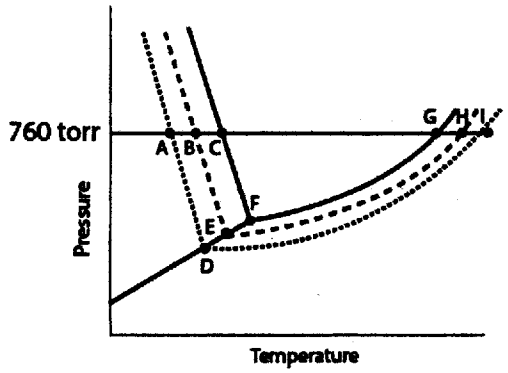
1. (10 marks)

(a) A 1.00 M solution of salt A (MW = 175.91 g/mol) has a density of 1.07 g/mL and a freezing point of -6.25°C. Determine the value of the van't Hoff factor *i* for salt A? K_f(water) = 1.86 °C·kg/mol

(b) Salt B (MW = 123.2 g/mol) is nonvolatile and has a van't Hoff factor *i*=2. Assume it dissociates completely. Determine the vapour pressure of a solution prepared from dissolving 2 g of B in a solution of 10 g of water and 10 g of methanol at 17°C. The vapour pressure of pure water is 14.55 mm Hg and the vapour pressure of pure methanol is 82.5 mm Hg at 17°C.

(c) From the following phase diagram of water identify (by writing the corresponding letter in the chart) the points which represent the normal boiling point of:

i) pure water ii) 1.0 *m* solution of salt A iii) 1.0 *m* solution of salt B



	Point
normal boiling point of water	
normal boiling point of 1.0 *m* solution of salt A	
normal boiling point of 1.0 *m* solution of salt B	

2. (10 marks)

Consider the gas-phase decomposition of NOBr:

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

(a) When 0.0200 mol of NOBr is added to an empty 1.00 L flask and the decomposition reaction is allowed to reach equilibrium at 300 K, the final concentration of NOBr is 0.0122 M.
Determine the equilibrium **concentrations of NO and Br_2 and K_c** for this reaction at 300 K.

(b) What is the value for K_p for this reaction?

(c) Which has the larger rate constant, the forward (k_f) or the reverse (k_r) reaction? Explain.

(d) If the reaction in a) is endothermic in the forward direction, circle the correct response (either "stays the same", "increase" or "decrease") below.

How will k_f, k_r, and K_c change if the <u>temperature is increased</u>?

i) k_f will	stay the same	increase	decrease
ii) k_r will	stay the same	increase	decrease
iii) K_c will	stay the same	increase	decrease

3. (12 marks)

Answer the following questions for the chemical reaction between carbon monoxide and hydrogen gas to produce liquid methanol.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(l) \qquad \Delta H^\circ = -128 \text{ kJ/mol}$$

(a) Given the standard entropies in the table below, is this reaction spontaneous under standard state conditions at 25°C?

$S^\circ_{CO(g)}$	198 J mol^{-1} K^{-1}
$S^\circ_{H2(g)}$	131 J mol^{-1} K^{-1}
$S^\circ_{CH3OH(l)}$	127 J mol^{-1} K^{-1}

(b) In what temperature range will this reaction be spontaneous under standard state conditions?

(c) What is the equilibrium constant for this reaction at 25°C and at 200°C?

(d) Does the magnitude of the equilibrium constant at different temperatures agree with the predicted spontaneity of the reaction at different temperatures?

4. (12 marks)

Consider the following half-reactions and E° values:

$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$ $E° = -0.25$ V

$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ $E° = -0.13$ V

(a) Write the overall reaction that occurs spontaneously under standard state conditions and circle the oxidizing agent in the equation.

(b) Write the cell notation for the voltaic cell that incorporates the above reaction

(c) What is the equilibrium constant, K, for the reaction in a)?

(d) If the $[Co^{2+}]$ remains 1.0 M and the $[Pb^{2+}]$ is reduced to 1.0×10^{-6} M, what is the effect on the cell? (Hint, calculate Q.)

(e) What is E_{cell} for the conditions described in d)?

(f) What is the cell potential when the cell described in d) reaches equilibrium? Also, calculate the equilibrium concentration of Pb^{2+}?

USEFUL EQUATIONS

$E=h\nu$ $\lambda=c/\nu$ $\lambda=h/m\nu$ $E_{photon}=h\nu_0 + E_k$

$PV=nRT$ $u_{rms} = (3RT/M)^{1/2}$

$\Delta T_b = K_b m$ $\Delta T_f = K_f m$ $\Pi=MRT$ $P_{solution}=X_{solvent}P_{solvent}$ $S_{gas}=K_H P_{gas}$

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

$K_p=K_c(RT)^{\Delta n}$; $\Delta n = c + d - (a + b)$

Arrhenius equation: $k = Ae^{-Ea/RT}$

First order reaction: $\ln\{[A]_0/[A]\} = kt$

Second order reaction: $1/[A] - 1/[A]_0 = kt$

Zero order reaction: $[A]= -kt + [A]_0$

$pH = -\log[H_3O^+]$ $pH + pOH = 14$ $K_a \times K_b = K_w$ $pH = pK_a + \log\frac{[base]}{[acid]}$

$q = nC\Delta T$ $w = -P\Delta V$ $\Delta E = q + w$ $\Delta H = \Delta E + P\Delta V$

$S = k\ln W$ $\Delta S = \frac{q}{T}$ $\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr}$

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\Delta H^\circ = \sum coeff_p \Delta H_f^\circ(pdts) - \sum coeff_r \Delta H_f^\circ(rcts)$$

$$\Delta S^\circ = \sum coeff_p S^\circ(pdts) - \sum coeff_r S^\circ(rcts)$$

$$\Delta G^\circ = \sum coeff_p \Delta G_f^\circ(pdts) - \sum coeff_r \Delta G_f^\circ(rcts)$$

$\Delta G = \Delta H - T\Delta S$ $\Delta G = \Delta G^\circ + RT\ln Q$ $\Delta G^\circ = -RT\ln K$ $\Delta G = -nFE$

$I = \frac{nC}{t}$ $E = E^\circ - \frac{RT}{nF}\ln Q$ $E = E^\circ - \frac{0.0592\ V}{n}\log Q$ (at 298.15 K)

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	$N_A = 6.0221367 \times 10^{23}$ mole^{-1}
Boltzmann's constant	$k = 1.380658 \times 10^{-23}$ J K^{-1}
Faraday's constant	$F = 9.6485309 \times 10^{4}$ C mole^{-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 mole^{-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 (N m^{-2}) = 760.0 mm Hg (torr) = 1.01325 bar

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}

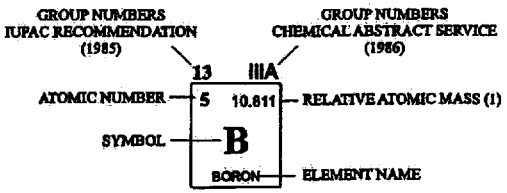
1 L atm = 101.325 J = 24.217 cal

ln x = 2.3026 log x

1 nm = 1×10^{-9}

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	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	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@netlinx.com)

Standard Reduction Potentials (in Volts), 25°C

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