

Topics in the June 2008 Exam Paper for CHEM1903

Click on the links for resources on each topic.

2008-J-2:

- [Nuclear and Radiation Chemistry](#)
- [Atomic Electronic Spectroscopy](#)
- [Bonding in H₂ - MO theory](#)
- [Bonding in O₂, N₂, C₂H₂, C₂H₄ and CH₂O](#)
- [Band Theory - MO in Solids](#)
- [Types of Intermolecular Forces](#)

2008-J-3:

- [Nuclear and Radiation Chemistry](#)

2008-J-4:

- [Bonding in O₂, N₂, C₂H₂, C₂H₄ and CH₂O](#)
- [Shape of Atomic Orbitals and Quantum Numbers](#)
- [Filling Energy Levels in Atoms Larger than Hydrogen](#)

2008-J-5:

- [Lewis Structures](#)
- [VSEPR](#)

2008-J-6:

- [Wave Theory of Electrons and Resulting Atomic Energy Levels](#)

2008-J-7:

- [Polar Bonds](#)
- [Types of Intermolecular Forces](#)
- [Wave Theory of Electrons and Resulting Atomic Energy Levels](#)

2008-J-8:

- [Thermochemistry](#)
- [First and Second Law of Thermodynamics](#)

2008-J-9:

- [Nitrogen in the Atmosphere](#)

2008-J-10:

- [Thermochemistry](#)
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2008-J-11:

- [Thermochemistry](#)
- [First and Second Law of Thermodynamics](#)

2008-J-13:

- [Electrochemistry](#)

2008-J-14:

- Electrochemistry
- First and Second Law of Thermodynamics

CONFIDENTIAL

FIRST SEMESTER EXAMINATION

JUNE 2008

TIME ALLOWED: THREE HOURS

GIVE THE FOLLOWING INFORMATION IN BLOCK LETTERS

FAMILY NAME		SID NUMBER	
OTHER NAMES		TABLE NUMBER	

INSTRUCTIONS TO CANDIDATES

- All questions are to be attempted. There are 23 pages of examinable material.
- Complete the written section of the examination paper in **INK**.
- Read each question carefully. Report the appropriate answer and show all relevant working in the space provided.
- The total score for this paper is 100. The possible score per page is shown in the adjacent tables.
- Each new short answer question begins with a •.
- Electronic calculators, including programmable calculators, may be used. Students are warned, however, that credit may not be given, even for a correct answer, where there is insufficient evidence of the working required to obtain the solution.
- Numerical values required for any question, standard electrode reduction potentials, a Periodic Table and some useful formulas may be found on the separate data sheets.
- Pages 14, 21, 23 and 28 are for rough working only.

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~~Multiple choice section~~

		Marks	
Pages	Max	Gained	
2-11	33		

Short answer section

Page	Marks		Marker
	Max	Gained	
12	6		
13	7		
15	7		
16	3		
17	4		
18	6		
19	6		
20	3		
22	6		
24	4		
25	5		
26	4		
27	6		
Total	67		

Marks
6

- In the spaces provided, explain the meaning of the following terms. You may use an example, equation or diagram where appropriate.

(a) antibonding molecular orbital

(b) emission spectroscopy

(c) half-life

(d) band gap

(e) dispersion interaction

(f) a triple bond

Marks
2

- Explain why a sustained fission chain reaction can only occur when a critical mass is prepared.

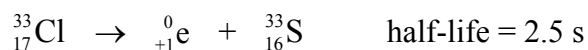
2

- The half life of ^3H is 12 years. Calculate how long it takes (rounded to the nearest year) for the activity of a sample of tritium to have dropped to 0.1% of its original value.

Answer:

3

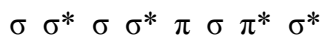
- Consider the following list of unstable isotopes and their decay mechanisms.



From this list, select the isotope that best satisfies the following requirements. Provide a reason for your choice in each case.

Requirement	Isotope	Reason for choice
Isotope used in medical imaging		
Decay represents the transformation of a neutron into a proton		
The isotope with the highest molar activity		

- The electronic energies of the molecular orbitals of homonuclear diatomics from the period starting with Li can be ordered as follows (with energy increasing from left to right):



Using this ordering by energy of the molecular orbitals, how many unpaired spins do you expect in the ground state configurations of each of B₂, C₂, N₂, O₂ and F₂?

Marks
3

B ₂	C ₂	N ₂	O ₂	F ₂

Consider the 15 species X₂⁻, X₂ and X₂⁺ where X is B, C, N, O or F. What is the maximum bond order found among these 15 species and which molecules or ions exhibit this bond order?

--

What is the minimum bond order found among these 15 species and which molecules or ions exhibit this bond order?

--

- Imagine a Universe X in which electrons had *three* possible spin states (*i.e.* with electron spin quantum numbers -1, 0 and +1) instead of the two they have in our universe. Assume that all other properties of electrons and nuclei in Universe X are identical to those in our universe.

4

What are the atomic numbers of the first two noble gases in Universe X?

--

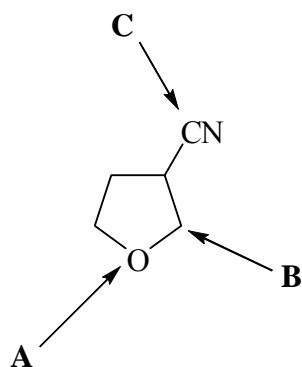
Write down the ground state electron configuration of the atom with atomic number 14 in Universe X.

--

How would the energy difference between the 2s and 2p orbitals in multi-electron atoms compare between our universe and Universe X? Give a brief explanation of your answer.

--

- Consider the molecule whose structure is shown below. Complete the table concerning the atoms **A**, **B** and **C** indicated by the arrows.



Marks
3

Selected atom	Number of lone pairs about the selected atom	Number of σ -bonds associated with the selected atom	Geometry of σ -bonds about the selected atom
A			
B			
C			

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- Moseley discovered experimentally in 1913 that the atomic number, Z , of an element is inversely proportional to the square root of the wavelength, λ , of fluorescent X-rays emitted when an electron drops from the $n = 2$ to the $n = 1$ shell.

$$i.e. \quad \frac{1}{\sqrt{\lambda}} = kZ$$

Derive an expression for the constant of proportionality, k , for a hydrogen-like atom which would allow the value of k to be theoretically calculated.

Marks
4

Marks
2

- Describe two physical properties of liquid or solid N₂ that distinguish it from liquid or solid H₂O.

2

- One problem with the Rutherford model of the atom was that there was nothing to stop the electrons from spiralling into the nucleus. Briefly explain how the quantum theory of the electrons resolved this problem.

2

- From the list of molecules below, select all the polar molecules and list them from left to right in order of increasing molecular dipole moment.

BF₃, CH₃Cl, CH₃F, CO₂, CF₄, NF₃

Marks
6

- Write a balanced equation for (i) the explosive decomposition, and (ii) the combustion in air, of TNT, $C_7H_5N_3O_6(s)$.

(i)

(ii)

What is the essential difference between these two processes?

What is the increase in the number of moles of gas (per mole of TNT consumed) for each of these two processes?

(i)

Answer:

(ii)

Answer:

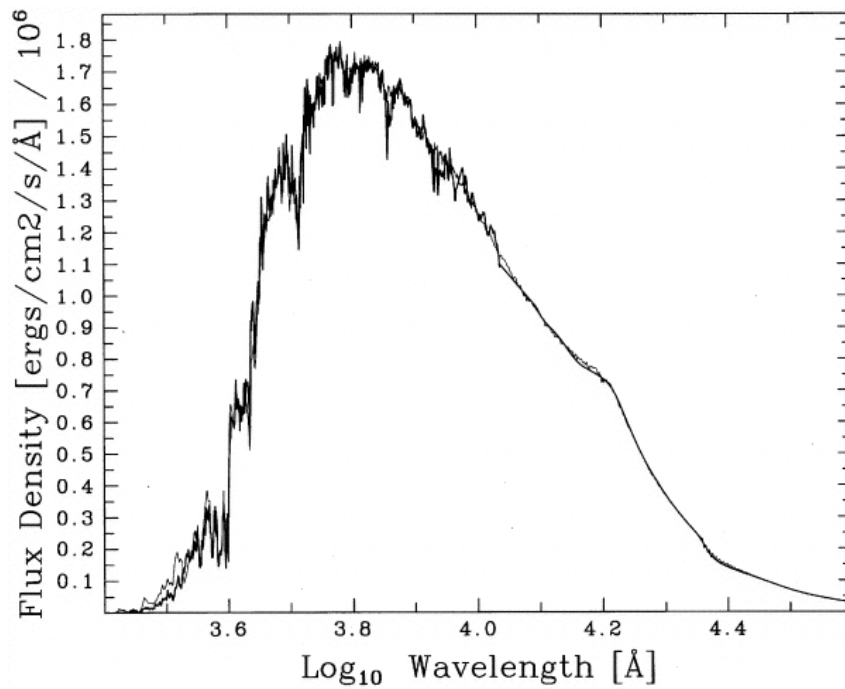
Which of these two processes releases more energy into the surroundings?

Data: $\Delta_f H^\circ(\text{TNT}) = 6.9 \text{ kJ mol}^{-1}$ $\Delta_f H^\circ(\text{CO(g)}) = -111 \text{ kJ mol}^{-1}$
 $\Delta_f H^\circ(\text{CO}_2(\text{g})) = -393 \text{ kJ mol}^{-1}$ $\Delta_f H^\circ(\text{H}_2\text{O(g)}) = -242 \text{ kJ mol}^{-1}$

Answer:

Estimate the surface temperature of the star Arcturus from its emission spectrum shown in the figure below.

Marks
3



Answer:

On the figure above, sketch the broad emission spectrum of a red giant, clearly showing the emission maximum and the overall intensity.

Marks
6

- A calorimeter containing 300.0 mL of water at 25 °C was calibrated as follows. A 1000.0 W heating coil was run for 10.0 s, after which time the temperature had increased by 7.5 °C. Calculate the heat capacity of the empty calorimeter. The specific heat of water is $4.184 \text{ J K}^{-1} \text{ g}^{-1}$.

Answer:

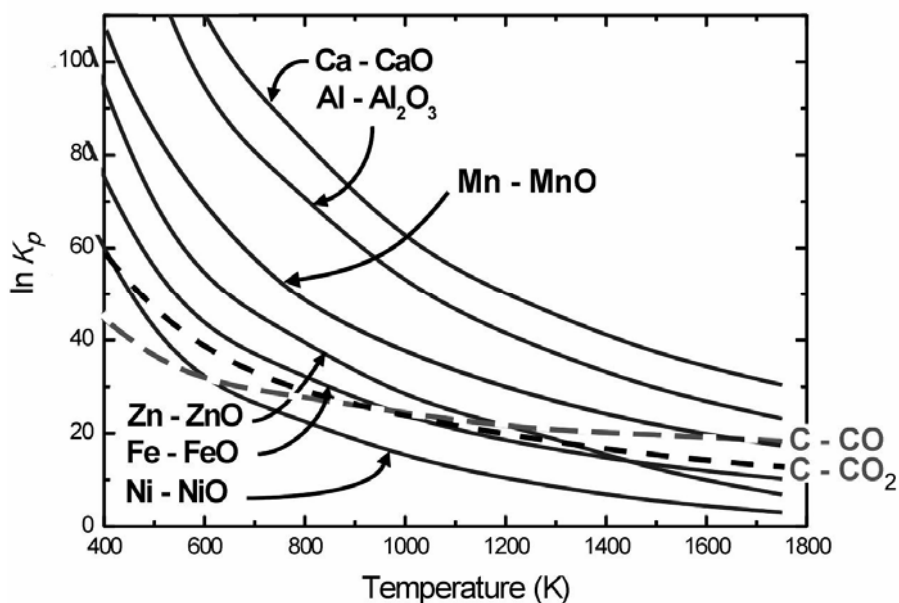
A solution containing 0.040 mol $\text{Ag}^+(\text{aq})$ was mixed with a second solution containing 0.050 mole $\text{Br}^-(\text{aq})$ in this calorimeter, causing $\text{AgBr}(\text{s})$ to precipitate. The temperature increased by 2.4 °C. Given the solubility product constant is $K_{\text{sp}}(\text{AgBr}) = 5 \times 10^{-13} \text{ M}^2$, calculate the equilibrium concentrations of $\text{Ag}^+(\text{aq})$ and $\text{Br}^-(\text{aq})$ present in the final solution of volume 320 mL.

[$\text{Ag}^+(\text{aq})$]:[$\text{Br}^-(\text{aq})$]:Calculate the enthalpy of solution of $\text{AgBr}(\text{s})$.

Answer:

- Use the figure below to help answer the following.

Marks
4



Write a balanced equation for the smelting of one of these metal oxides with coke in which a major product is CO_2 . Give the approximate temperature range over which this reaction is spontaneous and state what happens outside this temperature range.

Over what temperature range can ZnO be reduced by Fe ? What other metal could be used instead to increase the temperature range in which metallic Zn was produced?

THIS QUESTION CONTINUES ON THE NEXT PAGE.

Estimate the partial pressure of CO that would be expected at equilibrium in the smelting of ZnO by coke at 1500 K.

Marks
5

Metallic copper is produced by smelting chalcopyrite, $\text{CuFeS}_2(\text{s})$, directly in oxygen to produce iron oxides and SO_2 . Write a balanced equation for this reaction, and sketch the $\ln K_p$ versus temperature curve for Cu-CuO on the diagram on page 24. Clearly label the curve you have drawn.

- A voltaic cell consists of Zn^{2+}/Zn and Cu^{2+}/Cu half cells with initial concentrations of $[\text{Zn}^{2+}] = 1.00 \text{ M}$ and $[\text{Cu}^{2+}] = 0.50 \text{ M}$. Each half cell contains 1.00 L of solution.

Marks
4

What is the voltage of the cell at 20 °C after equilibrium has been reached?

What are the concentrations of the $\text{Zn}^{2+}(\text{aq})$ and the $\text{Cu}^{2+}(\text{aq})$ ions at 20 °C after equilibrium has been reached?

--	--

$[\text{Zn}^{2+}]_{\text{eq}} =$

$[\text{Cu}^{2+}]_{\text{eq}} =$

Marks
2

- Judging by the electrochemical series of standard reduction potentials, $\text{H}^+(\text{aq})$ should be reduced to $\text{H}_2(\text{g})$ by exposure to metallic Fe, which is oxidised to $\text{Fe}^{2+}(\text{aq})$. Why do we not see water on iron spontaneously generating hydrogen gas?

4

- State the Second Law of Thermodynamics, and explain how an exothermic process in a closed system changes the entropy of the surroundings.

The standard enthalpy and entropy of solution of poly(oxyethylene) in water are $\Delta H^\circ = -7.8 \text{ kJ mol}^{-1}$ and $\Delta S^\circ = -31 \text{ J K}^{-1} \text{ mol}^{-1}$. Use these data to predict whether the solubility of poly(oxyethylene) in water increases or decreases when the solution is warmed.

CHEM1901 - CHEMISTRY 1A (ADVANCED)
CHEM1903 - CHEMISTRY 1A (SPECIAL STUDIES PROGRAM)

DATA SHEET

Physical constants

Avogadro constant, $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

Faraday constant, $F = 96485 \text{ C mol}^{-1}$

Planck constant, $h = 6.626 \times 10^{-34} \text{ J s}$

Speed of light in vacuum, $c = 2.998 \times 10^8 \text{ m s}^{-1}$

Rydberg constant, $E_R = 2.18 \times 10^{-18} \text{ J}$

Boltzmann constant, $k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$

Permittivity of a vacuum, $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$

Gas constant, $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
 $= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$

Charge of electron, $e = 1.602 \times 10^{-19} \text{ C}$

Mass of electron, $m_e = 9.1094 \times 10^{-31} \text{ kg}$

Mass of proton, $m_p = 1.6726 \times 10^{-27} \text{ kg}$

Mass of neutron, $m_n = 1.6749 \times 10^{-27} \text{ kg}$

Properties of matter

Volume of 1 mole of ideal gas at 1 atm and 25 °C = 24.5 L

Volume of 1 mole of ideal gas at 1 atm and 0 °C = 22.4 L

Density of water at 298 K = 0.997 g cm⁻³

Conversion factors

1 atm = 760 mmHg = 101.3 kPa

1 Ci = 3.70×10^{10} Bq

0 °C = 273 K

1 Hz = 1 s⁻¹

1 L = 10⁻³ m³

1 tonne = 10³ kg

1 Å = 10⁻¹⁰ m

1 W = 1 J s⁻¹

1 eV = 1.602 × 10⁻¹⁹ J

Decimal fractions

Fraction	Prefix	Symbol
10 ⁻³	milli	m
10 ⁻⁶	micro	μ
10 ⁻⁹	nano	n
10 ⁻¹²	pico	p

Decimal multiples

Multiple	Prefix	Symbol
10 ³	kilo	k
10 ⁶	mega	M
10 ⁹	giga	G

CHEM1901 - CHEMISTRY 1A (ADVANCED)
CHEM1903 - CHEMISTRY 1A (SPECIAL STUDIES PROGRAM)

Standard Reduction Potentials, E°

Reaction	E° / V
$\text{Co}^{3+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Co}^{2+}(\text{aq})$	+1.82
$\text{Ce}^{4+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Ce}^{3+}(\text{aq})$	+1.72
$\text{MnO}_4^{-}(\text{aq}) + 8\text{H}^{+}(\text{aq}) + 5\text{e}^{-} \rightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}$	+1.51
$\text{Au}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Au}(\text{s})$	+1.50
$\text{Cl}_2 + 2\text{e}^{-} \rightarrow 2\text{Cl}^{-}(\text{aq})$	+1.36
$\text{O}_2 + 4\text{H}^{+}(\text{aq}) + 4\text{e}^{-} \rightarrow 2\text{H}_2\text{O}$	+1.23
$\text{Pt}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Pt}(\text{s})$	+1.18
$\text{MnO}_2(\text{s}) + 4\text{H}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Mn}^{3+} + 2\text{H}_2\text{O}$	+0.96
$\text{NO}_3^{-}(\text{aq}) + 4\text{H}^{+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{NO}(\text{g}) + 2\text{H}_2\text{O}$	+0.96
$\text{Pd}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Pd}(\text{s})$	+0.92
$\text{Ag}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Cu}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Cu}(\text{s})$	+0.53
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Sn}^{2+}(\text{aq})$	+0.15
$2\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g})$	0 (by definition)
$\text{Fe}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Fe}(\text{s})$	-0.04
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Ni}(\text{s})$	-0.24
$\text{Cd}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cd}(\text{s})$	-0.40
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Fe}(\text{s})$	-0.44
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Cr}(\text{s})$	-0.74
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O} + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^{-}(\text{aq})$	-0.83
$\text{Cr}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cr}(\text{s})$	-0.89
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Al}(\text{s})$	-1.68
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Mg}(\text{s})$	-2.36
$\text{Na}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Ca}(\text{s})$	-2.87
$\text{Li}^{+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Li}(\text{s})$	-3.04

CHEM1901 - CHEMISTRY 1A (ADVANCED)
CHEM1903 - CHEMISTRY 1A (SPECIAL STUDIES PROGRAM)

Useful formulas

<p>Quantum Chemistry</p> $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $E = -Z^2 E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$ $4.5k_B T = hc/\lambda$ $T = 2.898 \times 10^6/\lambda(\text{nm})$	<p>Electrochemistry</p> $\Delta G^\circ = -nFE^\circ$ <p>Moles of $e^- = It/F$</p> $E = E^\circ - (RT/nF) \times 2.303 \log Q$ $= E^\circ - (RT/nF) \times \ln Q$ $E^\circ = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E^\circ - \frac{0.0592}{n} \log Q \text{ (at 25 }^\circ\text{C)}$
<p>Acids and Bases</p> $pK_w = \text{pH} + \text{pOH} = 14.00$ $pK_w = \text{p}K_a + \text{p}K_b = 14.00$ $\text{pH} = \text{p}K_a + \log \{ [A^-] / [HA] \}$	<p>Gas Laws</p> $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$
<p>Colligative properties</p> $\pi = cRT$ $P_{\text{solution}} = X_{\text{solvent}} \times P^\circ_{\text{solvent}}$ $p = kc$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	<p>Kinetics</p> $t_{1/2} = \ln 2/k$ $k = Ae^{-E_a/RT}$ $\ln[A] = \ln[A]_0 - kt$ $\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$
<p>Radioactivity</p> $t_{1/2} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ $^{14}\text{C age} = 8033 \ln(A_0/A_t) \text{ years}$	<p>Thermodynamics & Equilibrium</p> $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G = \Delta G^\circ + RT \ln Q$ $\Delta G^\circ = -RT \ln K$ $K_p = K_c (RT)^{\Delta n}$
<p>Miscellaneous</p> $A = -\log \frac{I}{I_0}$ $A = \epsilon cl$ $E = -A \frac{e^2}{4\pi\epsilon_0 r} N_A$	<p>Mathematics</p> <p>If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$</p> $\ln x = 2.303 \log x$

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 HYDROGEN H 1.008																	2 HELIUM He 4.003
3 LITHIUM Li 6.941	4 BERYLLIUM Be 9.012											5 BORON B 10.81	6 CARBON C 12.01	7 NITROGEN N 14.01	8 OXYGEN O 16.00	9 FLUORINE F 19.00	10 NEON Ne 20.18
11 SODIUM Na 22.99	12 MAGNESIUM Mg 24.31											13 ALUMINIUM Al 26.98	14 SILICON Si 28.09	15 PHOSPHORUS P 30.97	16 SULFUR S 32.07	17 CHLORINE Cl 35.45	18 ARGON Ar 39.95
19 POTASSIUM K 39.10	20 CALCIUM Ca 40.08	21 SCANDIUM Sc 44.96	22 TITANIUM Ti 47.88	23 VANADIUM V 50.94	24 CHROMIUM Cr 52.00	25 MANGANESE Mn 54.94	26 IRON Fe 55.85	27 COBALT Co 58.93	28 NICKEL Ni 58.69	29 COPPER Cu 63.55	30 ZINC Zn 65.39	31 GALLIUM Ga 69.72	32 GERMANIUM Ge 72.59	33 ARSENIC As 74.92	34 SELENIUM Se 78.96	35 BROMINE Br 79.90	36 KRYPTON Kr 83.80
37 RUBIDIUM Rb 85.47	38 STRONTIUM Sr 87.62	39 YTRIUM Y 88.91	40 ZIRCONIUM Zr 91.22	41 NIObIUM Nb 92.91	42 MOLYBDENUM Mo 95.94	43 TECHNETIUM Tc [98.91]	44 RUTHENIUM Ru 101.07	45 RHODIUM Rh 102.91	46 PALLADIUM Pd 106.4	47 SILVER Ag 107.87	48 CADMIUM Cd 112.40	49 INDIUM In 114.82	50 TIN Sn 118.69	51 ANTIMONY Sb 121.75	52 TELLURIUM Te 127.60	53 IODINE I 126.90	54 XENON Xe 131.30
55 CAESIUM Cs 132.91	56 BARIUM Ba 137.34	57-71	72 HAFNIUM Hf 178.49	73 TANTALUM Ta 180.95	74 TUNGSTEN W 183.85	75 RHENIUM Re 186.2	76 OSMIUM Os 190.2	77 IRIDIUM Ir 192.22	78 PLATINUM Pt 195.09	79 GOLD Au 196.97	80 MERCURY Hg 200.59	81 THALLIUM Tl 204.37	82 LEAD Pb 207.2	83 BISMUTH Bi 208.98	84 POLONIUM Po [210.0]	85 ASTATINE At [210.0]	86 RADON Rn [222.0]
87 FRANCIUM Fr [223.0]	88 RADIUM Ra [226.0]	89-103	104 RUTHERFORDIUM Rf [261]	105 DUBNIUM Db [262]	106 SEABORGIUM Sg [266]	107 BOHRIUM Bh [262]	108 HASSIUM Hs [265]	109 MEITNERIUM Mt [266]	110 DARMSTADTIUM Ds [271]	111 ROENTGENIUM Rg [272]							

LANTHANIDES	57 LANTHANUM La 138.91	58 CERIUM Ce 140.12	59 PRASEODYMIUM Pr 140.91	60 NEODYMIUM Nd 144.24	61 PROMETHIUM Pm [144.9]	62 SAMARIUM Sm 150.4	63 EUROPIUM Eu 151.96	64 GADOLINIUM Gd 157.25	65 TERBIUM Tb 158.93	66 DYSPROSIUM Dy 162.50	67 HOLMIUM Ho 164.93	68 ERBIUM Er 167.26	69 THULIUM Tm 168.93	70 YTTERBIUM Yb 173.04	71 LUTETIUM Lu 174.97
ACTINIDES	89 ACTINIUM Ac [227.0]	90 THORIUM Th 232.04	91 PROTACTINIUM Pa [231.0]	92 URANIUM U 238.03	93 NEPTUNIUM Np [237.0]	94 PLUTONIUM Pu [239.1]	95 AMERICIUM Am [243.1]	96 CURIUM Cm [247.1]	97 BERKELIUM Bk [247.1]	98 CALIFORNIUM Cf [252.1]	99 EINSTEINIUM Es [252.1]	100 FERMIUM Fm [257.1]	101 MENDELEVIUM Md [256.1]	102 NOBELIUM No [259.1]	103 LAWRENCIUM Lr [260.1]