Topics in the June 2006 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2006-J-2:

- Wave Theory of Electrons and Resulting Atomic Energy Levels
- Material Properties (Polymers, Liquid Crystals, Metals, Ceramics)

2006-J-3:

- Nuclear and Radiation Chemistry

2006-J-4:

- Bonding - MO theory (larger molecules)

2006-J-5:

- Wave Theory of Electrons and Resulting Atomic Energy Levels
- Lewis Structures
- VSEPR

2006-J-6:

- Gas Laws
- Thermochemistry

2006-J-7:

- Thermochemistry
- First and Second Law of Thermodynamics

2006-J-8:

- Thermochemistry
- First and Second Law of Thermodynamics

2006-J-9:

- Chemical Equilibrium
- Equilibrium and Thermochemistry in Industrial Processes

2006-J-10:

- Material Properties (Polymers, Liquid Crystals, Metals, Ceramics)
- Types of Intermolecular Forces

2006-J-11:

- Electrochemistry

2006-J-12:

- Nitrogen Chemistry and Compounds

22/05(a) **The University of Sydney**

CHEMISTRY 1A - CHEM1101

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2006 **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 15, 20, 23 and 28 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-13	44	

Short answer section

Page	Marks: Max	Gained		Marker
14	6			
16	6			
17	5			
18	5			
19	6			
21	5			
22	5			
24	2			
25	4			
26	8			
27	4			
Total	56			
Check total				

Marks
6

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

(a) Hund's rule

(b) electron affinity

(c) nuclear fusion

(d) diamagnetic

(e) p-type semiconductor

(f) π bond

Marks

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide. **3**

$$^{63}_{28}\mathrm{Ni} \rightarrow\ ^{63}_{29}\mathrm{Cu} + \boxed{}$$

$$^{53}_{26}\mathrm{Fe} +\ ^{0}_{-1}\mathrm{e} \rightarrow \boxed{}$$

$$^{28}_{14}\mathrm{Si} +\ ^{2}_{1}\mathrm{H} \rightarrow\ ^{1}_{0}\mathrm{n} + \boxed{}$$

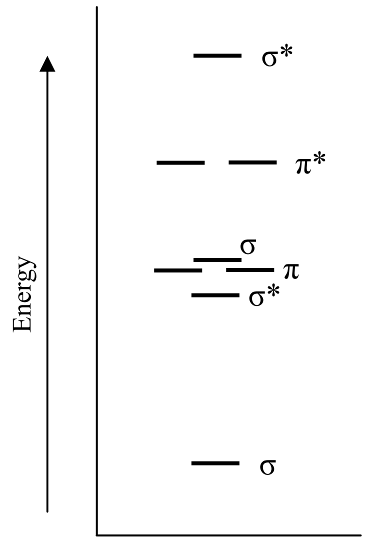
- Calculate the energy (in J) and the wavelength (in nm) of the photon of radiation emitted when the electron in Be^{3+} drops from an $n = 3$ state to an $n = 2$ state. **3**

Energy:	Wavelength:

Marks
5

- The N_2^+ ion plays a role in the colourful display of the Northern Lights (the *Aurora Borealis*).

The molecular orbital energy level diagram provided shows the energies of the orbitals for the valence electrons in the N_2^+ ion. Indicate on this diagram the ground state electronic configuration of N_2^+ using the arrow notation for electron spins.



Calculate the bond order of N_2^+.

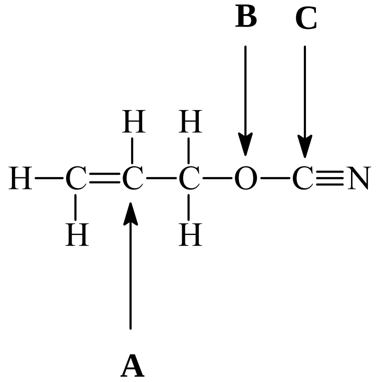
Indicate the lowest energy electron excitation in this ion by identifying the initial and final states of the electron undergoing the excitation.

The line at 3914 Å (391.4 nm) in the emission spectrum of the *Aurora Borealis* is due to N_2^+ returning to its ground state. Calculate the energy gap (in eV) between the molecular orbitals involved in this transition.

Answer:

Marks

- With respect to the molecule sketched below, answer the following questions concerning the selected atoms indicated by arrows as **A**, **B** and **C**. **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			

- Identify two factors that explain the origin of the discrete energy levels of electrons in atoms? **2**

Marks

- At room temperature and pressure (RTP), 1 mole of an ideal gas occupies 24.45 L. Calculate the molar volume of the same ideal gas in the stratosphere, where the pressure is 0.020 atm and the temperature is 200 K. **2**

Answer:

- Two blocks of metal, as shown in the table below, are placed in intimate contact in an insulated environment. **4**

Metal	Iron	Copper
Mass (g)	30.0	20.0
Initial *T* (°C)	0.0	100.0
c (J g^{-1} K^{-1})	0.450	0.387

In which direction will the heat flow? Write "from Fe to Cu" or "from Cu to Fe".

What is the final temperature of the system?

Answer:

Marks
5

- Calculate the molar enthalpy of combustion of ethylene (C_2H_4) using bond dissociation energies.

Data:

Bond	Bond enthalpy (in kJ mol^{-1})	Bond	Bond enthalpy (in kJ mol^{-1})
C–H	413	C=C	614
O–H	467	C=O	799
		O=O	498

Answer:

The heat of combustion of ethane (C_2H_6) is –1560 kJ mol^{-1}, while that of ethanol (C_2H_5OH) is –1367 kJ mol^{-1}. Comment on which of ethylene, ethane and ethanol is the most efficient fuel.

Marks
5

- Silicon tetrachloride ($SiCl_4$) is produced annually on a kilotonne scale for making transistor-grade silicon. It can be made directly from the elements (reaction 1), or, more cheaply, by heating sand and graphite with chlorine gas (reaction 2). If water is present, some $SiCl_4$ may be lost in an unwanted side-reaction (reaction 3).

1. $Si(s) + 2Cl_2(g) \rightarrow SiCl_4(g)$
2. $SiO_2(s) + 2C(s) + 2Cl_2(g) \rightarrow SiCl_4(g) + 2CO(g)$
3. $SiCl_4(g) + 2H_2O(g) \rightarrow SiO_2(s) + 4HCl(g)$ $\Delta H° = -139.5$ kJ mol^{-1}

Calculate the heats of reaction of reactions 1 and 2.

Compound	$\Delta H°_f$ / kJ mol^{-1}
$SiO_2(s)$	-910.9
$HCl(g)$	-92.3
$H_2O(g)$	-241.8
$CO(g)$	-110.5

$\Delta H°_{(reaction\ 1)}$ =

$\Delta H°_{(reaction\ 2)}$ =

Write down the new reaction that is the sum of reactions 2 and 3. What is the heat of reaction for this new reaction?

Reaction:

$\Delta H°$ =

Marks
2

- The thermal decomposition of lithium peroxide produces oxygen.

$$2Li_2O_2(s) \rightleftharpoons 2Li_2O(s) + O_2(g)$$

A 1.0 g sample of Li_2O_2 was placed in a closed container and heated to a temperature, where some, but not all, of the Li_2O_2 decomposes. The experiment is then repeated using a 2.0 g sample, heated to the same temperature in an identical container. How does the pressure of $O_2(g)$ produced vary between these two experiments? Explain.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
4

- List the following five solids in order of increasing melting points.

  NaCl, H_2, CH_4, H_2O, SiO_2

Briefly explain your ordering based on the types of forces that are involved.

List those that are electrical conductors when molten. Briefly explain your answers.

Marks

- Balance the following redox equation in acidic medium. **4**

$$HBrO_3(aq) + Bi(s) \rightarrow HBrO_2(aq) + Bi_2O_3(s)$$

Which species is the oxidizing agent?	
Which element is reduced?	
What is the oxidation number of Br before the reaction?	
How many electrons does each Bi gain or lose?	

- What is the role of the salt bridge in a voltaic cell and how is this accomplished? **4**

How is this role achieved in the lead acid battery?

- Identify four features of a compound that would make it a good explosive.

Marks
4

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

CHEM1101 - CHEMISTRY 1A

DATA SHEET

Physical constants

Avogadro constant, $N_A = 6.022 \times 10^{23}$ mol^{-1}
Faraday constant, $F = 96485$ C mol^{-1}
Planck constant, $h = 6.626 \times 10^{-34}$ J s
Speed of light in vacuum, $c = 2.998 \times 10^{8}$ m s^{-1}
Rydberg constant, $E_R = 2.18 \times 10^{-18}$ J
Boltzmann constant, $k_B = 1.381 \times 10^{-23}$ J K^{-1}
Gas constant, $R = 8.314$ J K^{-1} mol^{-1}
= 0.08206 L atm K^{-1} mol^{-1}
Charge of electron, $e = 1.602 \times 10^{-19}$ C
Mass of electron, $m_e = 9.1094 \times 10^{-31}$ kg
Mass of proton, $m_p = 1.6726 \times 10^{-27}$ kg
Mass of neutron, $m_n = 1.6749 \times 10^{-27}$ 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
0 °C = 273 K
1 L = 10^{-3} m^3
1 Å = 10^{-10} m
1 eV = 1.602×10^{-19} J
1 Ci = 3.70×10^{10} Bq
1 Hz = 1 s^{-1}

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

CHEM1101 - CHEMISTRY 1A

Standard Reduction Potentials, E°

Reaction	$E°$ / V
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82
$Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq)$	+1.72
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.50
$Cl_2 + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2 + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+1.23
$MnO_2(s) + 4H^+(aq) + e^- \rightarrow Mn^{3+} + 2H_2O$	+0.96
$Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$	+0.92
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Cu^+(aq) + e^- \rightarrow Cu(s)$	+0.53
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0 (by definition)
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	–0.04
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	–0.24
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	–0.74
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76
$2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	–0.83
$Cr^{2+}(aq) + 2e^- \rightarrow Cr(s)$	–0.89
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	–1.68
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	–2.36
$Na^+(aq) + e^- \rightarrow Na(s)$	–2.71
$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$	–2.87
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04

CHEM1101 - CHEMISTRY 1A

Useful formulas

Quantum Chemistry $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $4.5k_BT = hc/\lambda$ $E = Z^2E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$	**Electrochemistry** $\Delta G° = -nFE°$ $Moles\ of\ e^- = It/F$ $E = E° - (RT/nF) \times 2.303 \log Q$ $= E° - (RT/nF) \times \ln Q$ $E° = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E° - \frac{0.0592}{n} \log Q$ (at 25 °C)
Acids and Bases $pK_w = pH + pOH = 14.00$ $pK_w = pK_a + pK_b = 14.00$ $pH = pK_a + \log\{[A^-] / [HA]\}$	**Gas Laws** $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$
Colligative properties $\pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $p = kc$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	**Kinetics** $t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
Radioactivity $t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age $= 8033 \ln(A_0/A_t)$	**Thermodynamics & Equilibrium** $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT \ln Q$ $\Delta G° = -RT \ln K$ $K_p = K_c (RT)^{\Delta n}$
Polymers $R_g = \sqrt{\frac{nl_0^2}{6}}$	**Mathematics** If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$

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 YTTRIUM **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]									

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 BERKELLIUM **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]