Topics in the June 2006 Exam Paper for CHEM1903

Click on the links for resources on each topic.

2006-J-2:

- Bonding in H_2 - MO theory
- Bonding in O_2, N_2, C_2H_2, C_2H_4 and CH_2O
- Band Theory - MO in Solids

2006-J-3:

- Nuclear and Radiation Chemistry
- Wave Theory of Electrons and Resulting Atomic Energy Levels

2006-J-4:

- Ionic Bonding

2006-J-5:

- Bonding in O_2, N_2, C_2H_2, C_2H_4 and CH_2O

2006-J-6:

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

2006-J-7:

- Thermochemistry
- First and Second Law of Thermodynamics
- Nitrogen in the Atmosphere

2006-J-8:

- Thermochemistry

2006-J-9:

- Equilibrium and Thermochemistry in Industrial Processes

2006-J-10:

- Electrochemistry

2006-J-11:

- Electrolytic Cells

2006-J-12:

- First and Second Law of Thermodynamics

22/45(a) **The University of Sydney**

CHEMISTRY 1A (ADVANCED) - CHEM1901

CHEMISTRY 1A (SPECIAL STUDIES PROGRAM) - CHEM1903

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 19, 23, 24 and 28 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-13	44	

Short answer section

	Marks			
Page	Max	Gained		Marker
14	6			
15	8			
16	3			
17	4			
18	6			
20	7			
21	4			
22	4			
25	3			
26	6			
27	5			
Total	56			

Marks
6

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

(a) Pauli exclusion principle

(b) electronegativity

(c) ionic bond

(d) paramagnetic

(e) n-type semiconductor

(e) σ bond

Marks

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

$$^{55}_{26}\text{Fe} + ^{0}_{-1}\text{e} \rightarrow \boxed{}$$

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

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

- Identify the decay mechanism for the following three unstable nuclides given that the only stable isotopes of Pr and Eu are $^{141}_{59}\text{Pr}$, $^{151}_{63}\text{Eu}$ and $^{153}_{63}\text{Eu}$. There are no stable isotopes of Rn. **3**

Isotope	Nuclear Decay Mechanism
$^{142}_{59}\text{Pr}$	
$^{150}_{63}\text{Eu}$	
$^{222}_{86}\text{Rn}$	

- Identify two specific features of atomic structure that can only be explained by reference to the wave-like nature of electrons. Give reasons. **2**

Marks

- The ionic solids NaCl, LiF, KF and LiCl, all have the same crystal structure. Assuming only electrostatic interactions are involved, use the information below to organise these four ionic solids in order of increasing energy of the crystal lattice. **2**

ion	radius (10^{-12} m)	ion	radius (10^{-12} m)
Li^+	76	F^-	133
Na^+	102	Cl^-	181
K^+	138		

Working

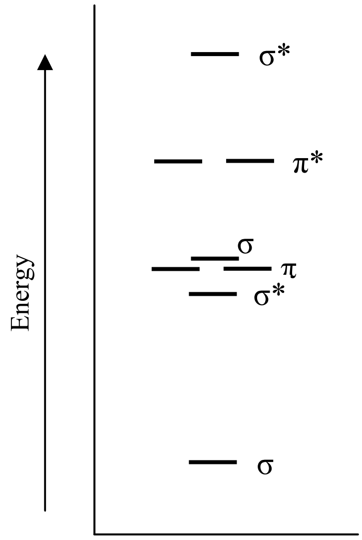
Increasing energy of the crystal lattice →

- Explain why CsCl, NaCl and ZnS have different crystal structures. **1**

Marks
4

- The molecular orbital energy level diagram below is for the valence electrons of the O_2^+ ion.

  Indicate the ground state electronic configuration of O_2^+ using the arrow notation for electron spins on the provided molecular orbital energy level diagram.



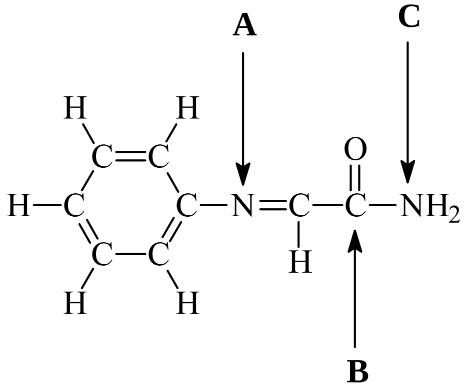
Calculate the bond order of O_2^+.

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

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks

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

- 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

- Write the equation whose enthalpy change represents the standard enthalpy of formation of hydrazine, $N_2H_4(g)$. **4**

Write the equation whose enthalpy change represents the enthalpy of combustion of hydrazine, $N_2H_4(g)$ to produce water vapour.

Given the following data, calculate the standard enthalpy of formation of $N_2H_4(g)$.

$\Delta H°_f (H_2O(g)) = –242$ kJ mol$^{–1}$

$\Delta H°_{comb} (N_2H_4(g)) = –580$ kJ mol$^{–1}$

Answer:

- Estimate the temperature of Mars given its radius of 3400 km and the solar power density at its surface of 590 J m$^{–2}$ s$^{–1}$. Assume an average albedo of 16% and zero Greenhouse effect. **3**

Answer:

Marks
4

- In an experiment, 1.76 g of sodium nitrate was dissolved in water inside a calorimeter. Give a balanced equation for the reaction that took place.

The temperature of the solution was found to decrease by 1.22 °C. If the heat capacity of the calorimeter was 77.0 J K^{-1} and the heat capacity of the solution was 268 J K^{-1}, determine the molar heat of reaction.

Answer:

How long would it take a 250 W power supply to reheat the calorimeter to its starting temperature?

Marks
4

- At 773 K, the following reaction has an equilibrium constant, K_p, of 1.52×10^{-5} atm^{-2}.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

If 0.0200 mol of ammonia were introduced into an evacuated 1.00 L container at 773 K, what would be the partial pressures of N_2, H_2 and NH_3 at equilibrium?

$P(N_2)$ =	$P(H_2)$ =	$P(NH_3)$ =

Marks
3

- Refer to the electrochemical potentials on the data sheet.

  Show that Fe^{2+}(aq) is not stable under 1 atm O_2 in a 1 M solution of HCl. What happens to Fe^{2+}?

  Show Fe(s) is stabilised by galvanizing with Zn(s).

  Show Cu^{+}(aq) is not stable in water. What would happen to Cu^{+}(aq)?

Marks
6

- In the chlor-alkali process $H_2(g)$, $OH^-(aq)$ and $Cl_2(g)$ are produced by the electrolysis of a concentrated solution of sodium chloride. Explain how hydrogen gas is produced at the cathode, and why chlorine gas rather than oxygen gas forms at the anode.

A chlor-alkali plant produces 42.3 tonne of Cl_2 per day. Calculate the minimum current used. (1 tonne = 1000 kg)

Answer:

Calculate the amount of H_2 produced (in mol) and estimate the daily energy available to the plant through combustion of this hydrogen. $\Delta H^\circ_f(H_2O(g)) = -242\ kJ\ mol^{-1}$

Answer:

Marks
5

- State the Second Law of Thermodynamics, and explain how the enthalpy of reaction is related to the entropy change of the surroundings.

Give an example of a chemical reaction or a chemical process that corresponds to each of the following.

$\Delta S > 0$, $\Delta H > 0$

$\Delta S > 0$, $\Delta H < 0$

$\Delta S < 0$, $\Delta H < 0$

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

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

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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

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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 $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$

June 2006

CHEM1901/1903

22/45(b)

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]