Topics in the November 2006 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2006-N-2:

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

2006-N-3:

- Nuclear and Radiation Chemistry

2006-N-4:

- Periodic Table and the Periodic Trends
- Wave Theory of Electrons and Resulting Atomic Energy Levels
- Filling Energy Levels in Atoms Larger than Hydrogen
- Atomic Electronic Spectroscopy

2006-N-5:

- Bonding - MO theory (larger molecules)

2006-N-6:

- Lewis Structures
- VSEPR

2006-N-7:

- Periodic Table and the Periodic Trends
- Material Properties (Polymers, Liquid Crystals, Metals, Ceramics)
- Types of Intermolecular Forces

2006-N-8:

- Thermochemistry
- First and Second Law of Thermodynamics

2006-N-9:

- Gas Laws
- Thermochemistry
- First and Second Law of Thermodynamics

2006-N-10:

- Chemical Equilibrium

2006-N-11:

- Electrolytic Cells

2006-N-12:

- Bonding - MO theory (H_2)
- Electrochemistry
- Batteries and Corrosion

22/07(a)

The University of Sydney

CHEMISTRY 1A - CHEM1101

SECOND SEMESTER EXAMINATION

CONFIDENTIAL

NOVEMBER 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 21 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 13 and 24 are for rough working only.

OFFICIAL USE ONLY

Multiple choice section

	Marks	
Pages	Max	Gained
2-11	41	

Short answer section

	Marks			
Page	Max	Gained		Marker
12	5			
14	6			
15	7			
16	5			
17	5			
18	4			
19	3			
20	4			
21	5			
22	7			
23	8			
Total	59			

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

Marks
5

(a) allotropes

(b) ionisation energy

(c) diamagnetic

(d) intrinsic semiconductor

(e) σ bond

Marks

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide. **4**

$$^{212}_{83}\text{Bi} \rightarrow \, ^{208}_{81}\text{Tl} + \square$$

$$^{8}_{4}\text{Be} + \square \rightarrow \, ^{12}_{6}\text{C}$$

$$^{14}_{7}\text{N} + \, ^{1}_{0}\text{n} \rightarrow \, ^{1}_{1}\text{p} + \square$$

What is a common source of the neutrons in the previous reaction?

- Explain why solid α emitters are generally considered as low risk radioisotopes while gaseous α emitters are high risk. **2**

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks

- Calculate the energy (in J) and the wavelength (in nm) of the photon of radiation absorbed when the electron in B^{4+} jumps from the $n = 3$ state to the $n = 4$ state. **3**

Energy:	Wavelength:

- Explain why the atomic radius of elements are observed to decrease from left to right across a period. **2**

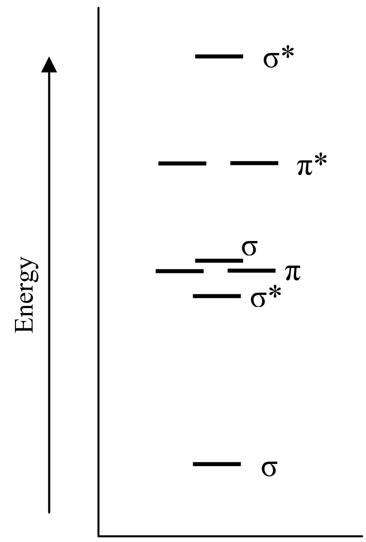
- Explain why samples must be atomised for atomic absorption spectrometry, but not for X-ray spectrometry. **2**

Marks
5

- The NO molecule plays an important signalling role in the human body.

How many valence electrons are in the molecule NO?

The molecular orbital energy level diagram provided shows the energies of the orbitals for the valence electrons in the NO molecule. Indicate on this diagram the ground state electronic configuration of NO using the arrow notation for electron spins.



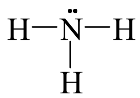
Calculate the bond order of NO.

Is the NO molecule diamagnetic or paramagnetic? Explain your answer.

Would removing an electron from NO to form NO^+ strengthen or weaken the bond between the two atoms? Explain your answer.

Marks
5

- Complete the table below showing the number of valence electrons, the Lewis structure and the predicted shape of each of the following species.

Formula	Total number of valence electrons	Lewis structure	Geometry of species
e.g. NH_3	8		trigonal pyramidal
NO_3^-			
HCN			

Which of NH_3, NO_3^- and HCN have a non-zero dipole moment?

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

3

- Glucose is a common food source. The net reaction for its metabolism in humans is:

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

Calculate $\Delta H°$ for this reaction given the following heats of formation.

$\Delta H°_f\ (C_6H_{12}O_6(s)) = –1274\ \text{kJ mol}^{–1}$

$\Delta H°_f\ (CO_2(g)) = –393\ \text{kJ mol}^{–1}$

$\Delta H°_f\ (H_2O(l)) = –285\ \text{kJ mol}^{–1}$

Answer:

If the combustion of glucose is carried out in air, water is produced as a vapour. Calculate $\Delta H°$ for the combustion of glucose in air given that

$H_2O(l) \rightarrow H_2O(g)$ $\Delta H° = +44\ \text{kJ mol}^{–1}$

Answer:

THIS QUESTION CONTINUES ON THE NEXT PAGE

Marks
4

Will ΔS be different for the two oxidation reactions? If so, how will it differ and why?

Calculate the mass of carbon dioxide produced by the complete oxidation of 1.00 g of glucose.

Answer:

Calculate the volume of this mass of carbon dioxide at 0.50 atm pressure and 37 °C.

Answer:

Marks
5

- Consider the following reaction.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

An experiment was conducted in which 0.1000 mol of $N_2O_4(g)$ was introduced into a 1.00 L flask. After equilibrium had been established at 100 °C, the concentration of $N_2O_4(g)$ was found to be 0.0491 M. Calculate the equilibrium constant, K_c, for the reaction as written at 100 °C.

K_c =

Use your calculated value for K_c to calculate whether a mixture of $N_2O_4(g)$ (0.120 M) and $NO_2(g)$ (0.550 M) is at equilibrium at 100 °C? If not, in which direction will it move?

Marks

- A chemical engineer dissolves a mixture of NaBr and $MgCl_2$ in water and decomposes it in an electrolytic cell. Predict the substance formed at each electrode and write balanced half reactions and the overall cell reaction. **4**

- What mass of $PbSO_4$ is reduced at the cathode when a lead-acid storage battery is charged for 1.5 hours with a constant current of 10.0 A? **3**

Marks

- Lead sulfate is used as a white pigment and also in car batteries. Its solubility in water at 25 °C is 4.25×10^{-3} g per100 mL of solution. Write an equation for the dissolution of lead sulfate in water and determine K_{sp} at 25 °C. **3**

K_{sp} =

- A voltaic cell consists of Ni/Ni^{2+} and Co/Co^{2+} half cells with initial concentrations of $[Ni^{2+}]$ = 0.80 M and $[Co^{2+}]$ = 0.20 M. What is the initial E_{cell} at 298 K? **5**

E_{cell} =

What is the value of the equilibrium constant, K, for this cell?

K =

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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
$Br_2 + 2e^- \rightarrow 2Br^-(aq)$	+1.10
$MnO_2(s) + 4H^+(aq) + e^- \rightarrow Mn^{3+} + 2H_2O$	+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
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–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** $t_{½} = \ln 2/k$ $k = Ae^{-E_a/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln \frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
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 $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$

November 2006

CHEM1101 – CHEMISTRY 1A

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]

22/07(b)