Topics in the June 2007 Exam Paper for CHEM1903

Click on the links for resources on each topic.

2007-J-2:

- Nuclear and Radiation Chemistry
- Filling Energy Levels in Atoms Larger than Hydrogen
- Bonding in O_2, N_2, C_2H_2, C_2H_4 and CH_2O
- Band Theory - MO in Solids
- Types of Intermolecular Forces

2007-J-3:

- Nuclear and Radiation Chemistry

2007-J-4:

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

2007-J-5:

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

2007-J-6:

- Types of Intermolecular Forces
- Polar Bonds
- Bonding in H_2 - MO theory
- Bonding in O_2, N_2, C_2H_2, C_2H_4 and CH_2O

2007-J-7:

- Thermochemistry
- First and Second Law of Thermodynamics
- Nitrogen Chemistry and Compounds

2007-J-8:

- Thermochemistry
- First and Second Law of Thermodynamics
- Chemical Equilibrium

2007-J-9:

- Thermochemistry

2007-J-10:

- Thermochemistry
- First and Second Law of Thermodynamics

2007-J-11:

- Equilibrium and Thermochemistry in Industrial Processes

2007-J-12:

- Electrolytic Cells

2007-J-13:

- First and Second Law of Thermodynamics

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CHEMISTRY 1A (ADVANCED) - CHEM1901

CHEMISTRY 1A (SPECIAL STUDIES PROGRAM) - CHEM1903

CONFIDENTIAL

FIRST SEMESTER EXAMINATION

JUNE 2007 **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 22 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.
- Page 24 is for rough working only.

OFFICIAL USE ONLY

Multiple choice section

	Marks	
Pages	Max	Gained
2-12	33	

Short answer section

Page	Marks			Marker
	Max	Gained		
12	6			
13	8			
14	5			
15	5			
16	7			
17	6			
18	5			
19	4			
20	4			
21	7			
22	5			
23	5			
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) diamagnetic

(b) covalent bond

(c) nucleogenesis

(d) hydrogen bond

(e) Hund's rule

(f) electrical conductor

Marks

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

$$^{36}_{17}\text{Cl} + ^{0}_{-1}\text{e} \rightarrow \square$$

$$^{238}_{92}\text{U} \rightarrow ^{4}_{2}\alpha + \square$$

$$^{238}_{92}\text{U} + ^{12}_{6}\text{C} \rightarrow 4\,^{1}_{0}\text{n} + \square$$

- The half life of ^{90}Sr is 29 years. Calculate the remaining activity (in Bq) of a sample containing ^{90}Sr after 100 years given that the initial activity was 1000 Bq. **2**

Answer:

- The three unstable isotopes $^{33}_{17}\text{Cl}$, $^{77}_{36}\text{Kr}$ and $^{27}_{12}\text{Mg}$ are unsuitable for use in medical imaging. For each isotope, provide a reason why it is unsuitable. The following data may be of use: **3**

$$^{33}_{17}\text{Cl} \rightarrow ^{0}_{+1}\text{e} + ^{33}_{16}\text{S} \qquad \text{half-life} = 2.5\text{ s}$$

$$^{77}_{36}\text{Kr} \rightarrow ^{0}_{+1}\text{e} + ^{77}_{35}\text{Br} \qquad \text{half-life} = 75\text{ minutes}$$

$$^{27}_{12}\text{Mg} \rightarrow ^{0}_{-1}\text{e} + ^{27}_{13}\text{Al} \qquad \text{half-life} = 9.5\text{ minutes}$$

Marks
5

- The electronic configuration of the molecular oxygen dianion in its ground state is, in order (from left to right) of increasing energy: $\sigma^2\ \sigma^{*2}\ \sigma^2\ \sigma^{*2}\ \sigma^2\ \pi^4\ \pi^{*4}$

What is the bond order of O_2^{2-}?

Is O_2^{2-} paramagnetic or diamagnetic? Explain your answer.

How many of the valence electrons in O_2^{2-} are in 'lone pairs' according to Lewis theory?

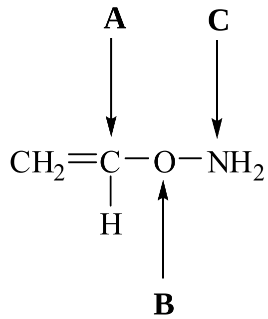
On the electron configuration of O_2^{2-} below, indicate by arrows the molecular orbitals that contain the electron 'lone pairs'.

$\sigma^2\ \sigma^{*2}\ \sigma^2\ \sigma^{*2}\ \sigma^2\ \pi^4\ \pi^{*4}$

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 Li^{2+} drops from an $n = 4$ state to an $n = 2$ state. **2**

Energy =	Wavelength =

Marks

- Describe two physical properties of liquid or solid water that distinguishes it from 'normal' liquids or solids. **3**

Identify one property of the water *molecule* that is responsible for at least one of the physical properties you described above. Your answer should include both the molecular property and the physical property associated with it.

- Describe one consequence of molecular shape involving *non-polar* molecules. **2**

- Molecules with multiple resonance structures are said to be "resonance stabilised". Briefly explain the origin of this extra stability in terms of electron waves and molecular orbitals. **2**

Marks
6

- Write a balanced equation for the combustion of methylhydrazine, $CH_3NHNH_2(g)$.

Using bond enthalpies, estimate the enthalpy of combustion of methylhydrazine.

Bond enthalpies:

Bond	ΔH / kJ mol^{-1}	Bond	ΔH / kJ mol^{-1}
C–N	285	O–H	464
N–N	159	O=O	498
C–H	416	C=O	806
N–H	391	N≡N	945

Answer:

Liquid methylhydrazine and liquid oxygen can be used as a rocket fuel. Calculate the calorific value (in kJ g^{-1}) of this fuel.

Answer:

When methylhydrazine is used as a rocket fuel, the usual oxidant is dinitrogen tetroxide rather than liquid oxygen. Why?

Marks

- Estimate the average temperature of Mercury given the solar power density at its surface of 9150 J m^{-2} s^{-1}, and assuming an average albedo of 6% and zero Greenhouse effect. **2**

Answer:

- The equilibrium constant for the dissolution of silver iodide at 25 °C is 1.5×10^{-16} M^2. Calculate the equilibrium concentrations of Ag^+(aq) and I^-(aq) if 0.200 mol of AgI(s) were dispersed in 1.0 L of (a) water, and (b) 0.0050 M aqueous solution of KI. **3**

(a)	(b)

Marks
4

- A calorimeter containing 300 mL of water at 25 °C was calibrated as follows. A 1000 W heating coil was run for 10 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 J K^{-1} g^{-1}.

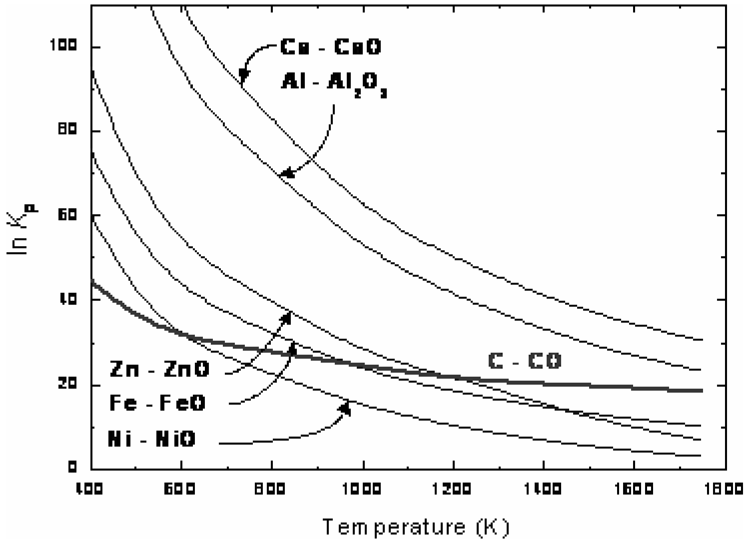
Answer:

15.0 g of sodium nitrite was dissolved into this calorimeter, and the temperature of the solution was found to decrease by 2.6 °C. Calculate the enthalpy of solution of sodium nitrite.

Answer:

Marks
4

- Use the figure below to help answer the following.



Write a balanced equation for the smelting of NiO by coke. In what temperature range will this process be spontaneous?

Why are (a) aluminium and (b) tungsten not recovered from their oxides by smelting with coke? What alternative processes are used and why?

Marks
7

- The first step in the production of sulfuric acid is the production of SO_2 by one of three main routes. Give the equation for SO_2 production by sulfur burning.

What is the equilibrium constant for this reaction?

Explain why this is done industrially using compressed air and at high temperatures.
$\Delta H_f^o(SO_2) = -297$ kJ mol^{-1}

Give the equation for the production of SO_2 by spent acid regeneration using a 1:1 ratio of H_2SO_4 and H_2S.

Give the equation for the roasting of a metal sulphide, MS, in a metallurgical plant.

In the final step, H_2SO_4 is produced by adding SO_3 to concentrated H_2SO_4 to produce "oleum". Why is the reaction $SO_3 + H_2O \rightarrow H_2SO_4$ not used directly?

Marks

- 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. On the basis of reduction potentials, $O_2(g)$ should be produced at the anode instead of $Cl_2(g)$. Explain the formation of Cl_2. **2**

- A certain aluminium refinery produces Al(s) via the Hall-Herault process using ten electrolytic cells in parallel, each operating at a current of 220,000 A. What mass of aluminium (in tonnes) is produced each day? **3**

Answer:

Calculate the mass of carbon anodes consumed each day in such a process.

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.

Formic acid HCOOH, can dimerise in the gas phase according to the reaction

$$2HCOOH \rightleftharpoons (HCOOH)_2$$

with a standard enthalpy and entropy of dimerisation of $\Delta H° = -62$ kJ mol^{-1} and $\Delta S° = -150$ J K^{-1} mol^{-1} respectively. Predict the temperature-dependence of the dimerisation reaction.

Draw a structure that shows the bonding in the dimer.

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}

Permittivity of a vacuum, $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 J^{-1} m^{-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}

1 tonne = 10^3 kg

1 W = 1 J 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

CHEM1901 - CHEMISTRY 1A (ADVANCED)

CHEM1903 - CHEMISTRY 1A (SPECIAL STUDIES PROGRAM)

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
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O$	+1.51
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.50
$Cl_2 + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2 + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+1.23
$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s)$	+1.18
$MnO_2(s) + 4H^+(aq) + e^- \rightarrow Mn^{3+} + 2H_2O$	+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
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	–0.40
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–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

CHEM1901 - CHEMISTRY 1A (ADVANCED)

CHEM1903 - CHEMISTRY 1A (SPECIAL STUDIES PROGRAM)

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 $\ln(A_0/A_t)$ years	**Thermodynamics & Equilibrium** $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT \ln Q$ $\Delta G° = -RT \ln K$ $K_p = K_c (RT)^{\Delta n}$
Miscellaneous $A = -\log 10 \frac{I}{I_0}$ $A = \varepsilon cl$ $E = -A \frac{e^2}{4\pi\varepsilon_0 r} N_A$	**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]	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 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]