22/06(a) **The University of Sydney**

CHEMISTRY 1A - CHEM1101

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2005 **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.
- Pages 15, 20, 23, 25 and 28 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-13	40	

Short answer section

Page	Marks			Marker
	Max	Gained		
14	6			
16	8			
17	6			
18	7			
19	5			
21	4			
22	6			
24	5			
26	8			
27	5			
Total	60			
Check total				

Marks
6

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

(a) Pauli exclusion principle

(b) orbital

(c) p-type semiconductor

(d) positron

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks

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

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

$${}^{3}_{2}\text{He} + {}^{1}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + \square$$

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

- Calculate the atomic mass of sulfur from the isotope information provided. **2**

Isotope	Mass of isotope (a.m.u.)	Relative abundance
^{32}S	31.97207	95.0%
^{33}S	32.97146	0.76%
^{34}S	33.96786	4.22%
^{36}S	35.96709	0.014%

Answer:

- Calculate the molar activity of ^{43}K (in Ci), given its half-life of 22.4 hours. **3**

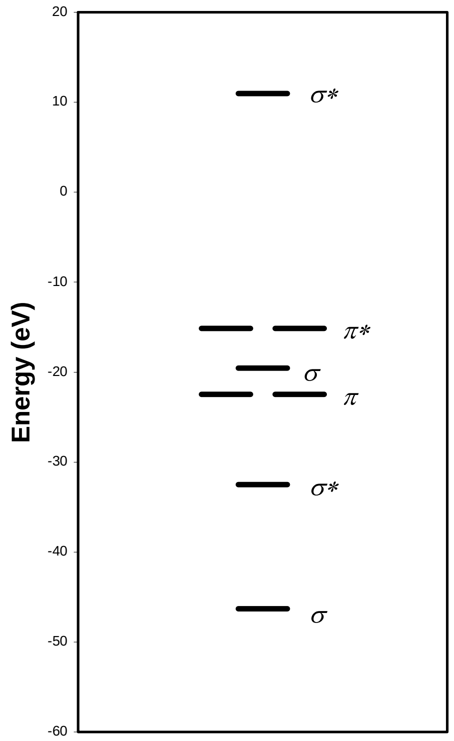
Answer:

Marks

- The following relate to the electronic structure of the O_2^+ molecular ion. **4**

How many valence electrons are there in O_2^+?

Complete the MO diagram for the ground state electronic configuration of O_2^+ by inserting an arrow to represent each valence electron.



What is the bond order of O_2^+?

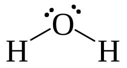
Do you expect O_2^+ to be paramagnetic? Explain your answer.

- Sketch the following wave functions as lobe representations. **2**

(a) a 2*p* atomic orbital	(b) a *σ** molecular orbital

Marks

- Complete the table below showing the number of valence electrons, a Lewis structure and the predicted shape of each of the following species. **5**

Formula	Number of valence electrons	Lewis structure	Name of molecular shape
e.g. H_2O	8		Bent (angular)
H_2CO			
CH_3Cl			

Which, if either, of H_2CO and CH_3Cl will have a dipole moment?

- Using the following electronegativity data, decide which one or more of the oxides of C, Te, Zn and Mg would be classified as containing ionic bonds. Briefly explain your answer. **2**

Element	Electronegativity
O	3.5
C	2.5
Te	2.1
Zn	1.4
Mg	1.2

Marks

- Calculate the energy (in J) and wavelength (in nm) expected for an emission associated with an electronic transition from *n* = 4 to 3 in the B^{4+} ion. **3**

Energy =	Wavelength =

- Describe how EITHER the *photoelectric effect* OR the *visible spectrum of hydrogen* contributed to the development of quantum mechanics. **2**

Marks
4

- Methane, CH_4, represents an increasingly important fuel. Write the balanced chemical equation for the combustion of methane.

Calculate the mass of CO_2 that would be produced by the combustion of 1.00 kg of methane.

Answer:

Calculate the volume of CO_2 produced at 0 °C and 1 atm.

Answer:

In an inefficient combustion reaction some of the methane gas may escape into the atmosphere, thereby decreasing the amount of CO_2 produced. Would such a leakage lead to a greater or lesser enhancement of the Greenhouse Effect? Why?

Marks

- Write the equation whose enthalpy change represents the standard enthalpy of formation of NO(g). **3**

Given the following data, calculate the standard enthalpy of formation of NO(g).

$$N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H° = 66.6 \text{ kJ mol}^{-1}$$

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H° = –114.1 \text{ kJ mol}^{-1}$$

Answer:

- Hydrazine, N_2H_4, burns completely in oxygen to form $N_2(g)$ and $H_2O(g)$. Use the bond enthalpies given below to estimate the enthalpy change for this process. **3**

Bond	Bond enthalpy (kJ mol^{-1})	Bond	Bond enthalpy (kJ mol^{-1})
N–H	391	O=O	498
N–N	158	O–O	144
N=N	470	O–H	463
N≡N	945	N–O	214

Answer:

Marks

- The value of the equilibrium constant, K_c, for the following reaction is 0.118 mol L^{-1}. **2**

$$2CO_2(g) + N_2(g) \rightleftharpoons 2CO(g) + 2NO(g)$$

What is the equilibrium concentration of CO(g) if the equilibrium concentration of $[CO_2(g)]$ = 0.392 M, $[N_2(g)]$ = 0.419 M and [NO(g)] = 0.246 M?

Answer:

- When hydrogen cyanide (HCN) is dissolved in water it dissociates into ions according to the following equation. **3**

$$HCN(aq) \rightleftharpoons H^+(aq) + CN^-(aq)$$

The equilibrium constant for this reaction is $K_c = 6.2 \times 10^{-10}$ mol L^{-1}. If 1.00 mol of HCN is dissolved to make 1.00 L of solution, calculate the percentage of HCN that will be dissociated.

Answer:

Marks

- Calculate the mass of aluminium metal that would be produced by the electroreduction of Al^{3+} by a current of 2.5×10^5 A for a period of 1.0 hour. **4**

Answer:

Explain why, in the Hall-Heroult process, a molten mixture of Al_2O_3 and Na_3AlF_6 is electrolysed, rather than either an aqueous solution of Al^{3+} or molten Al_2O_3.

- In the chlor-alkali process OH^-(aq) and Cl_2(g) are produced from the electrolysis of a saturated solution of sodium chloride. Write the half-reactions for the production of each of these. **4**

OH^-

Cl_2

Compare the oxidation potential of Cl^- to that of water and explain why Cl^- is oxidised preferentially.

Marks

- Calculate the standard electrochemical potential for the following reaction. **3**

$$3Zn(s) + 2Cr^{3+}(aq) \rightleftharpoons 3Zn^{2+}(aq) + 2Cr(s)$$

Answer:

Use the Nernst equation to calculate the relative cation concentrations at 298 K for which the cell potential, $E = 0$.

Answer:

- Fluorine and chlorine are both in Group 17. Briefly explain why HF exhibits hydrogen bonding but HCl does not. **2**

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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

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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
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	+1.23
$Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$	+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
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	–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

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Useful formulas

Quantum Chemistry $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $4.5k_BT = hc/\lambda$ $E = Z^2E_R(1/n^2)$	**Radioactivity** $t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age = $8033 \ln(A_0/A_t)$
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 $\pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $p = kc$ $\Delta T_f = K_fm$ $\Delta T_b = K_bm$	**Kinetics** $t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
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)	**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]