22/04(a)

The University of Sydney

CHEMISTRY 1A - CHEM1101

SECOND SEMESTER EXAMINATION

CONFIDENTIAL

NOVEMBER 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 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 21 and 24 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-11	36	

Short answer section

Page	Marks Max	Marks Gained		Marker
12	11			
13	4			
14	10			
15	4			
16	7			
17	3			
18	3			
19	7			
20	4			
22	4			
23	7			
Total	64			

Marks

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

$$^{14}_{7}\mathrm{N} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{15}_{8}\mathrm{O} + \square$$

$$^{20}_{10}\mathrm{Ne} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{20}_{9}\mathrm{F} + \square$$

$$e^{+} + e^{-} \rightarrow \square$$

- In the spaces provided, explain the meanings of the following terms. You may use an example or diagram where appropriate. **8**

(a) Pauli exclusion principle

(b) electron affinity

(c) metallic radius

(d) alpha particle

	Marks
• Use the relationship $E_k = ½mv^2$ to calculate the velocity of an electron accelerated by 150 V, and hence calculate its wavelength.	**2**

Velocity:	Wavelength:

• Calculate the atomic mass of chromium from the isotope information provided.	**2**

Isotope	Mass of isotope (a.m.u.)	Relative abundance
^{50}Cr	49.946046	4.35%
^{52}Cr	51.940509	83.79%
^{53}Cr	52.940651	9.5%
^{54}Cr	53.938882	2.36%

Answer:

- Sketch the lobe representations of the following wavefunctions.

Marks 4

(a) a 2*s* atomic orbital	(b) a π^* molecular orbital

- Explain the meaning of the following terms. Use an example or diagram where appropriate.

Marks 6

(a) band gap

(b) ionic bonding

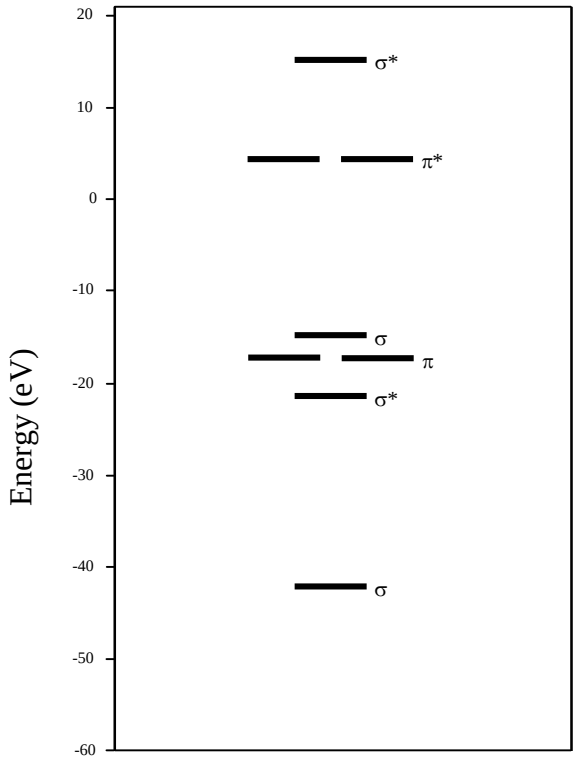
(c) allotrope

Marks 4

- The CN radical plays an important role in combustion and in interstellar chemistry.

How many valence electrons are there in CN?

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

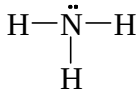


What is the bond order of CN?

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks

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

Formula	Number of valence electrons	Lewis structure	Geometry of species
e.g. NH_3	8		trigonal pyramidal
ClF_5			
NO_2^-			

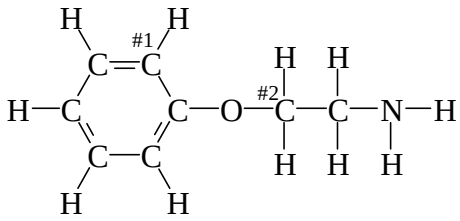
Which of NH_3, ClF_5 and NO_2^- have a non-zero dipole moment?

- What is the approximate value of the most intense wavelength emitted by the star Proxima Centauri, which has a temperature of 2700 K? **2**

Answer:

Marks 3

- What are the approximate bond angles at the carbon atoms labelled #1 and #2 in the following compound?



C#1 C#2

The infrared spectrum of this compound shows a strong absorption at 3500 cm^{-1}. Explain this observation in terms of the functional groups present in the molecule.

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	Marks
• Sketch an enthalpy diagram showing water vapour, water and ice. Show transitions to indicate melting, freezing, boiling, condensing and subliming. Indicate the sign of ΔH for each transition.	**3**

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Marks

- In an experiment at 20 °C and 101 kPa, 40.0 mL of $CO_2(g)$ was mixed with 5.0 mL of water. After equilibration, the final volume was 39.0 mL. Calculate the mole fraction solubility of CO_2 in water. Assume the density of water is 1.0 g mL^{-1}. **4**

Answer:

- Automobile airbags are inflated by the decomposition of sodium azide according to the following equation. **3**

$$6NaN_3(s) + Fe_2O_3(s) \rightarrow 3Na_2O(s) + 2Fe(s) + 9N_2(g)$$

What mass of NaN_3 is required to produce 75 L of nitrogen gas at 25 °C and 1.31 atm?

Answer:

Marks 4

- 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 1.000 L flask. After equilibrium had been established at a particular temperature, 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 that temperature.

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- Answer either Part **A** or Part **B**.

A: Describe the natural nitrogen biocycle and the influence of human activities on it.

OR

B: Discuss the role of nitrogen oxides in generating photochemical smog.

Marks 4

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- Compare and contrast the oxidation of methane to carbon dioxide in a fuel cell with the combustion of methane in a flame.

Marks 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

Answer:

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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
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+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

$E = h\nu = hc/\lambda$

$\lambda = h/mv$

$4.5k_BT = hc/\lambda$

$E = Z^2E_R(1/n^2)$

$\Delta x \cdot \Delta(mv) \geq h/4\pi$

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

$\pi = cRT$

$P_{solution} = X_{solvent} \times P°_{solvent}$

$p = kc$

$\Delta T_f = K_f m$

$\Delta T_b = K_b m$

Kinetics

$t_{½} = \ln 2/k$

$k = Ae^{-E_a/RT}$

$\ln[A] = \ln[A]_o - kt$

$$\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Electrochemistry

$\Delta G° = -nFE°$

Moles of $e^- = It/F$

$E = E° - (RT/nF) \times 2.303 \log Q$

$= E° - (RT/nF) \times \ln Q$

$E° = (RT/nF) \times 2.303 \log K$

$= (RT/nF) \times \ln K$

$$E = E° - \frac{0.0592}{n}\log Q \text{ (at 25 °C)}$$

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

$\ln x = 2.303 \log x$

November 2005

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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]