22/06(a)

The University of Sydney

CHEMISTRY 1A - CHEM1101

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2004 **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
2-11	34	

Short answer section

Page	Marks			Marker
	Max	Gained		
12	8			
13	8			
14	6			
15	7			
16	4			
17	7			
18	5			
19	4			
20	4			
21	6			
22	4			
23	3			
Total	66			

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

Marks
8

(a) Pauli exclusion principle

(b) nuclide

(c) conductance band

(d) ionisation energy

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**

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

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

$$^{15}_{7}\text{N} + ^{1}_{1}\text{p} \rightarrow ^{15}_{8}\text{O} + \square$$

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

Isotope	Mass of isotope (a.m.u.)	Relative abundance
^{28}Si	27.97693	92.21%
^{29}Si	28.97649	4.70%
^{30}Si	29.97376	3.09%

Answer:

- Calculate the molar activity of ^{3}H (in Curie), given its half-life of 12.26 years. **3**

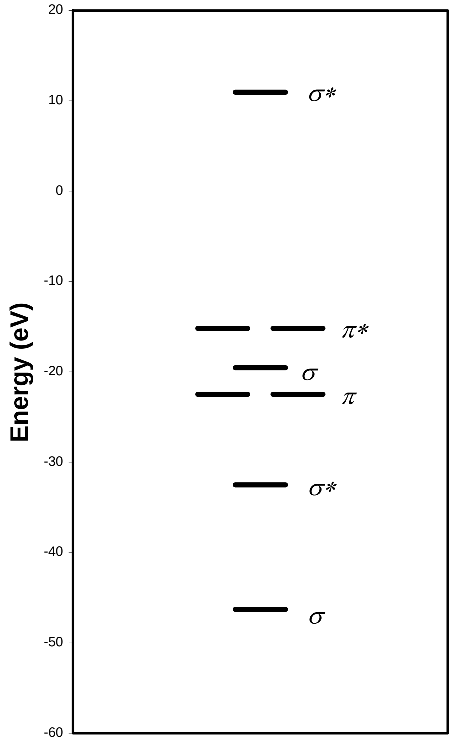
Answer:

Marks

- Oxygen gas, O_2, constitutes about 21% of the Earth's atmosphere. **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.

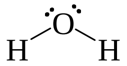
- Sketch the following wave functions as lobe representations. **2**

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

Marks

5

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

Formula	Number of valence electrons	Lewis structure	Name of molecular shape
e.g. H_2O	8		Bent (angular)
$SOCl_2$			
CCl_4			

Which, if either, of $SOCl_2$ and CCl_4 will have a dipole moment?

2

- 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.

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

Marks
4

- The ground state electron configuration of a sodium atom is [Ne] $3s^1$ and that of its first excited state is [Ne] $3s^0\ 3p^1$. The intense yellow light (wavelength 590 nm) from a sodium street lamp arises when an electron drops from the first excited state to the ground state. Calculate the energy associated with one photon of this yellow light.

Answer:

The ionisation energy of ground state sodium is 8.34×10^{-19} J per atom. Calculate the energy required to ionise the $3p$ electron of an excited sodium atom. Give your answer in kJ mol^{-1}.

Answer:

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Marks

- Water solutions of NaOH (100 mL, 2.0 M) and HCl (100 mL, 2.0 M), both at 24.6 °C, were mixed together in a coffee cup calorimeter. The temperature of the solution rose to 38.0 °C during the reaction process. Write a balanced chemical equation to describe the reaction in the calorimeter. **4**

Is the process an endothermic or exothermic reaction?

Assuming a perfect calorimeter, determine the standard enthalpy change for the neutralisation reaction. Assume the density of water is 1.00 g mL^{-1}. The heat capacity of water is 4.18 J K^{-1} g^{-1}.

- Explain why aluminium metal cannot be produced by the electrolysis of aqueous solutions of aluminium salts. Explain why aluminium is produced by the electrolysis of a molten mixture of Al_2O_3 and Na_3AlF_6 rather than by the electrolysis of molten Al_2O_3 alone. **3**

Marks 5

- RDX ($C_3H_6N_6O_6$) is a powerful explosive. Write the balanced chemical equation to describe the complete combustion of RDX to give water, carbon dioxide and nitrogen.

How does the equation for the explosive decomposition of RDX differ from the above equation?

What properties of RDX make it a good explosive?

How much heat is liberated from the complete combustion of 100 g of RDX?

Compound	$\Delta H_f°$ (kJ mol^{-1})
H_2O(l)	–286
CO_2(g)	–394
RDX(s)	+65

Answer:

Marks
4

- Aluminium metal is a very effective agent for reducing oxides to their elements. For example, it is used as a component of the solid fuel in the space shuttle, and in the thermite reaction shown in lectures:

$$Fe_2O_3(s) + 2Al(s) \rightarrow Al_2O_3(s) + 2Fe(s)$$

Write a balanced equation for the reduction of CuO(s) to the base metal by Al(s).

Given the following thermochemical data, evaluate the enthalpy change per gram of reactants for the CuO and Fe_2O_3 reactions above.

Compound	$\Delta H_f°$ (kJ mol^{-1})
Fe_2O_3	-821
Al_2O_3	-1668
CuO	-157

Answer (CuO):	Answer (Fe_2O_3):

Which set of reactants would make the better rocket fuel on the basis of most energy provided per mass of fuel (*i.e.* biggest “bounce per ounce”)?

Marks
4

- The standard dry cell (battery) has the following shorthand notation:

$$Zn(s) \mid Zn^{2+}(aq) \parallel MnO_2(s), Mn_2O_3(s) \mid graphite(s)$$

Which component of the battery is the anode?

Give the balanced half equation that takes place at the anode.

Which component of the battery is the cathode?

Give the balanced half equation that takes place at the cathode.

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Marks

- Explain the following features of the lead acid storage battery. **3**

  It has a relatively constant voltage.

  It needs no salt bridge.

  It can be recharged.

- Consider the following cell reaction. **3**

$$Pb(s) + Sn^{2+}(aq) \rightleftharpoons Pb^{2+}(aq) + Sn(s)$$

Use the Nernst equation to calculate the ratio of cation concentrations at 298 K for which the cell potential, E = 0. (See the data sheet for a table of standard reduction potentials.)

Answer:

Marks
4

- A saturated solution of iodine in water contains 0.330 g I_2 per litre, but more than this amount can dissolve in a potassium iodide solution because of the following equilibrium.

$$I^-(aq) + I_2(aq) \rightleftharpoons I_3^-(aq)$$

A 0.100 M KI solution dissolves 12.5 g of I_2 per litre, most of which is converted to $I_3^-(aq)$. Assuming that the concentration of $I_2(aq)$ in all saturated solutions is the same, calculate the equilibrium constant for the above reaction.

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
3

- Calcium oxide (lime) is a white crystalline solid with a melting point of 2572 °C. It is manufactured by heating limestone, coral, sea shells or chalk, which are mainly $CaCO_3$, to drive off carbon dioxide, according to the following reaction.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \qquad K_p = 1.16 \text{ atm at } 800\ °C$$

If 20.0 g of $CaCO_3$ were sealed in a 10.0 L container and heated to 800 °C, what percentage of $CaCO_3$ would remain unreacted at equilibrium?

Answer:

If 30.0 g of $CaCO_3$ were initially sealed in the container, how much more CaO would be produced?

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}

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}

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
$Cl_2 + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2 + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+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
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+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

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Useful formulas

Quantum Chemistry

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

$\lambda = h/mu$

$4.5k_BT = hc/\lambda$

Gas Laws

$PV = nRT$

$(P + n^2a/V^2)(V - nb) = nRT$

Kinetics

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

$t_{½} = \ln2/k$

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

Radioactivity

$A = \lambda N$

$\ln(N_0/N_t) = \lambda t$

^{14}C age = 8033 $\ln(A_0/A_t)$

Colligative properties

$\pi = cRT$

$p = kc$

$\Delta T_f = K_f m$

$\Delta T_b = K_b m$

Acids and Bases

$pK_w = pH + pOH = 14.00$

$pK_w = pK_a + pK_b = 14.00$

$pH = pK_a + \log\{[A^-] / [HA]\}$

Electrochemistry

$\Delta G° = -nFE°$

Moles of e^- $= It/F$

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

$E° = (RT/nF) \times 2.303 \log K$

$E = E° - \frac{0.0592}{n}\log Q$ (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

$\ln x = 2.303 \log x$

If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

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]