Topics in the November 2010 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2010-N-2:

- Periodic Table and the Periodic Trends

2010-N-3:

- Filling Energy Levels in Atoms Larger than Hydrogen
- Atomic Electronic Spectroscopy

2010-N-4:

- Nuclear and Radiation Chemistry

2010-N-5:

- Lewis Structures
- VSEPR

2010-N-6:

- Lewis Structures

2010-N-7:

- Thermochemistry

2010-N-8:

- Chemical Equilibrium
- Gas Laws

2010-N-9:

- Chemical Equilibrium

2010-N-10:

- Chemical Equilibrium

2010-N-11:

- First and Second Law of Thermodynamics

2010-N-12:

- Electrochemistry

2010-N-13:

- Electrochemistry
- Batteries and Corrosion

2207(a)

THE UNIVERSITY OF SYDNEY

CHEMISTRY 1A - CHEM1101

CONFIDENTIAL

SECOND SEMESTER EXAMINATION

NOVEMBER 2010 **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 •.
- Only non-programmable, University-approved calculators may be used.
- Students are warned 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 12 and 24 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-10	30	

Short answer section

Page	Marks			Marker
	Max	Gained		
11	6			
13	10			
14	8			
15	6			
16	5			
17	5			
18	6			
19	3			
20	5			
21	4			
22	6			
23	6			
Total	70			
Check total				

Marks
6

- The electron affinity is negative if energy is released upon addition of an electron. If it is positive, the resultant anion is unstable. Explain why beryllium has a positive electron affinity, while that of fluorine is highly negative.

Why is the ionisation potential of oxygen slightly smaller than nitrogen, despite being further across the period?

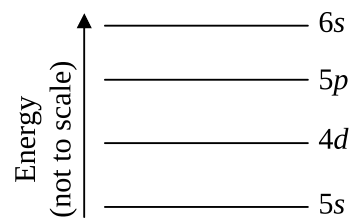
How is this related to the slightly positive electron affinity of nitrogen?

Marks
10

- Both strontium and strontianite are named after Strontian, a village in Scotland near which the mineral was first discovered. Strontium displays crimson (red) colouration in a flame. Give the ground state configuration for Sr.

Indicating only valence electrons, the electronic transition $5s5p \rightarrow 5s^2$ in strontium brings about 460 nm photons. Can this transition be responsible for the crimson colour of Sr flames? Explain.

Another transition, $5s4d \rightarrow 5s^2$, occurs at 496 nm. Show the transitions responsible for 460 nm and 496 nm photons on the energy level diagram to the right.



Calculate, in eV, the energy gap between the 4*d* and 5*p* orbitals of strontium.

Answer:

Explain why the 4*d* orbitals of strontium are of a higher energy than the 5*s* orbitals.

Electron spins cannot flip easily during a transition. Explain why the excited state of Sr, 5*s*5*p* with parallel spins, is long-lived.

Marks
8

- Sixteen unstable isotopes of strontium are known to exist. Of greatest importance are ^{90}Sr with a half-life of 28.78 years and ^{89}Sr with a half-life of 50.5 days. ^{90}Sr is found in nuclear fallout as it is a by-product of nuclear fission.

  Calculate the activity (in Bq) of 20.0 g of ^{90}Sr.

Answer:

Calculate the age (to the nearest year) of a sample of ^{90}Sr that has an activity one-eighth of a freshly prepared sample.

Answer:

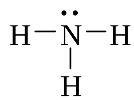
Determine the specific activity of ^{90}Sr in Ci g^{-1}.

Answer:

^{90}Sr presents a long-term health problem as it substitutes for calcium in bones. Comment on why Sr can substitute for Ca so readily.

Marks
6

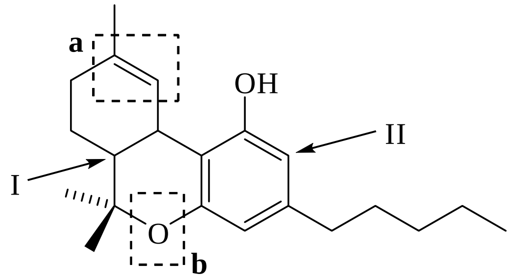
- Complete the table below showing the number of **valence** electrons, the Lewis structures and the predicted shapes of the following species. Ammonia, NH_3, is given as an example.

Formula	Number of electron pairs on central atom (discounting multiple bonds)	Lewis Structure	Name of molecular shape
NH_3	4		trigonal pyramidal
ClF_3			
PO_4^{3-}			

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks
5

- The structure of tetrahydrocannabinol, the active ingredient in marijuana, is shown below.



What is the molecular formula of tetrahydrocannabinol?	

Name the functional groups indicated in the boxes **a** and **b**.

a	
b	

What are the approximate bond angles at the carbon atoms labelled I and II?

Atom	Bond angle
I	
II	

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks
5

- Water solutions of NaOH (100.0 mL, 2.0 M) and HCl (100.0 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 ionic equation to describe the reaction in the calorimeter.

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 g^{-1} K^{-1}.

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks

- The reaction below is endothermic. **3**

$$N_2O_3(g) \rightleftharpoons NO(g) + NO_2(g)$$

Indicate whether the equilibrium will shift right, shift left, or remain unchanged when disturbed in the following ways.

adding more NO(g)	
increasing the pressure at constant temperature	
removing $NO_2(g)$	
increasing the volume at constant temperature	
adding some Ar(g)	
increasing the temperature at constant pressure	

- 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 63 L of nitrogen gas at 25 °C and 1.76 atm?

Answer:

Marks
3

- At 1000 K, a reaction mixture containing SO_2(g), O_2(g) and SO_3(g) was allowed to come to equilibrium in a reaction vessel. The reaction is:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

At equilibrium, the system was found to contain the following concentrations:
$[SO_2]$ = 0.00377 M, $[O_2]$ = 0.00430 M and $[SO_3]$ = 0.00185 M.
Calculate K_c for this reaction.

K_c =

If a mixture containing $[SO_2]$ = 0.0471 M, $[O_2]$ = 0.0280 M, and $[SO_3]$ = 0.00125 M is placed in the vessel, is the reaction at equilibrium? If not, which way will it shift in order to achieve equilibrium, right or left?

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Page Total:

Marks

- What does it mean to say that a reaction has reached equilibrium? **1**

- Consider the following equilibrium. **4**

$$Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g) \qquad K_c = 7.0 \text{ at } 400 \text{ K}$$

If 0.44 mol of Br_2 and 0.44 mol of Cl_2 are introduced into a 2.0 L container at 400 K, what are the equilibrium concentrations of $Br_2(g)$, $Cl_2(g)$ and $BrCl(g)$?

$[Br_2(g)]$ =	$[Cl_2(g)]$ =	$[BrCl(g)]$ =

Marks
4

- The heat of combustion of acetylene, C_2H_2(g), is –1301 kJ mol^{-1}. What is the heat of formation of acetylene gas?

  Data: $\Delta_f H°$ of CO_2(g) = –393.5 kJ mol^{-1} $\Delta_f H°$ of H_2O(l) = –285.8 kJ mol^{-1}

$\Delta_f H°$ =

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Page Total:

Marks
6

- The following redox reaction occurs in a voltaic cell:

$$2Sc(s) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 2Sc^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$$

Calculate the cell potential, E_{cell}, at 25 °C when $[Cr_2O_7^{2-}(aq)] = 6.2 \times 10^{-5}$ M, $[Sc^{3+}(aq)] = 0.35$ M, $[Cr^{3+}(aq)] = 0.75$ M and the pH is 1.85. The standard cell potential, $E°_{cell}$, for this cell is 3.70 V.

Answer:

What is the effect on the E_{cell} of decreasing the concentration of $Cr_2O_7^{2-}$ in the cathode compartment?

What is the effect on the E_{cell} of adding a 0.35 M solution of $Sc(NO_3)_3$ to the anode compartment?

Marks

- For each electrochemical cell described, write the half-reaction that occurs at each electrode and the overall balanced redox reaction. **4**

A voltaic cell constructed using a scandium rod in a solution of scandium(III) ions (Sc^{3+}/Sc) as one half-cell and a nickel rod in a solution of nickel(II) ions (Ni^{2+}/Ni) as the other half-cell.

Cathode	
Anode	
Overall cell reaction	

A voltaic cell in which oxidation of Cr to Cr^{3+} by O_2 in the presence of acid occurs.

Cathode	
Anode	
Overall cell reaction	

- An alkaline battery consists of a powdered Zn/gel anode and a C/MnO_2 cathode. At the anode, Zn is oxidised to Zn^{2+} which reacts with the OH^{-} ion present in the paste to form $Zn(OH)_2(s)$. Suppose that an alkaline battery was manufactured using Fe metal instead of Zn metal, and that the Fe was oxidised to Fe^{2+} at the anode. What effect would this have on the cell potential or emf of the battery? Explain your answer briefly. **2**

CHEM1101 - CHEMISTRY 1A

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

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
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O$	+1.51
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.50
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(g) + 7H_2O$	+1.36
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+1.23
$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s)$	+1.18
$MnO_2(s) + 4H^+(aq) + e^- \rightarrow Mn^{3+} + 2H_2O$	+0.96
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O$	+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
$Sc^{3+}(aq) + 3e^- \rightarrow Sc(s)$	–2.09
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	–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 $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $E = -Z^2E_R(1/n^2)$ $\Delta x\cdot\Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$ $T\lambda = 2.898 \times 10^6$ K nm	**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** $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$ $E_k = ½mv^2$
Radioactivity $t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age = 8033 $\ln(A_0/A_t)$ years	**Kinetics** $t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
Colligative Properties & Solutions $\Pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $c = kp$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	**Thermodynamics & Equilibrium** $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT \ln Q$ $\Delta G° = -RT \ln K$ $\Delta_{univ}S° = R \ln K$ $\ln\frac{K_2}{K_1} = \frac{-\Delta H°}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$
Miscellaneous $A = -\log\frac{I}{I_0}$ $A = \varepsilon cl$ $E = -A\frac{e^2}{4\pi\varepsilon_0 r}N_A$	**Mathematics** If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$ Area of circle = πr^2 Surface area of sphere = $4\pi r^2$

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]	112 COPERNICIUM **Cn** [283]						

LANTHANOIDS	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
ACTINOIDS	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]