Topics in the June 2014 Exam Paper for CHEM1001

Click on the links for resources on each topic.

2014-J-2:

- Molecules and Ions
- Chemical Equations
- Stoichiometry

2014-J-3:

- Lewis Model of Bonding

2014-J-4:

- Gas Laws

2014-J-5:

- Gas Laws
- Thermochemistry

2014-J-6:

- Lewis Model of Bonding
- VSEPR

2014-J-7:

- Lewis Model of Bonding
- Types of Intermolecular Forces

2014-J-8:

- VSEPR
- Chemical Equilibrium

2014-J-9:

- Lewis Model of Bonding
- The Periodic Table

2014-J-10:

- Introduction to Electrochemistry
- Electrochemistry
- Electrolytic Cells

2014-J-11:

- Thermochemistry
- First Law of Thermodynamics

2014-J-12:

- First Law of Thermodynamics

2201(a)

THE UNIVERSITY OF SYDNEY

FUNDAMENTALS OF CHEMISTRY 1A - CHEM1001

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2014 **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 19 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 15, 20, 22 and 24 are for rough working only.

OFFICIAL USE ONLY

Multiple choice section

	Marks	
Pages	Max	Gained
2-9	28	

Short answer section

Page	Marks Max	Gained		Marker
10	6			
11	6			
12	7			
13	6			
14	8			
16	5			
17	7			
18	8			
19	8			
21	6			
23	5			
Total	72			
Check Total				

Marks

- Complete the following table by filling in the compound name or formula as required. **4**

Name	Formula
	$CuSO_4$
	$NaNO_3$
magnesium chloride	
iron(III) oxide	

- What is the molarity of the solution formed when 0.50 g of aluminium fluoride is dissolved in 800.0 mL of water? **2**

Answer:

What is $[F^-]$ in this solution?

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Page Total:

Marks

- Explain, using words and diagrams, the type of bonding present in lithium oxide and compare this to the type of bonding in carbon dioxide. **6**

Carbon and oxygen can also react to form carbon monoxide. Draw the Lewis structure of this molecule.

Explain any difference in the polarity of carbon monoxide and carbon dioxide.

Marks 7

- Hydrazine (N_2H_4) reacts with dinitrogen tetraoxide (N_2O_4) to produce nitrogen and water, all in the gas phase, according to the following unbalanced equation.

$$N_2H_4(g) + N_2O_4(g) \rightarrow N_2(g) + H_2O(g)$$

Balance the above equation.

Describe the physical characteristics of a gas and sketch how the atoms of gaseous nitrogen might be represented in a container.

1.00 L of hydrazine was mixed with 1.00 L of dinitrogen tetraoxide at 25 °C and 1.00 atm pressure. Briefly explain Avogadro's Law and determine the mole ratio of hydrazine to dinitrogen tetraoxide present at room temperature?

Using the ideal gas equation, calculate the number of moles of hydrazine gas under these conditions.

Answer:

THIS QUESTION IS CONTINUED ON THE NEXT PAGE.

Marks
6

If the pressure remains constant at 1.00 atm, calculate the volume occupied by this mixture of gases after it was heated to 305 °C, before any reaction takes place.

Answer:

The molar heat capacity of N_2H_4 is 63 J K^{-1} mol^{-1} and that of N_2O_4 is 77 J K^{-1} mol^{-1}. Calculate the heat capacity of this mixture.

Answer:

Calculate the energy required to heat this mixture from 25 °C to 305 °C.

Answer:

Calculate the maximum mass of nitrogen gas that could be produced in this reaction.

Answer:

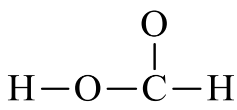
Marks
8

- Complete the following table. The central atom is underlined.

Species	Lewis structure	Molecular geometry
<u>N</u>H_3		
<u>S</u>O_3		
<u>I</u>Cl_3		
<u>I</u>Cl_4^-		

Marks
5

- Complete the Lewis structure of formic acid below by adding double bond(s) and lone pair(s).



Formic acid can form dimers in which two molecules are paired by mutual hydrogen bonding. Draw a dimer of formic acid, clearly showing the hydrogen bonds between the molecules.

Formic acid may lose H^+ from the oxygen to give a formate ion, shown in Equation 1.

$$HCOOH(aq) \rightleftharpoons HCOO^-(aq) + H^+(aq) \qquad \text{Equation 1}$$

Draw a Lewis structure of the formate ion and use it to illustrate the concept of resonance.

Comment on the carbon-oxygen bond lengths in formic acid and the carbon-oxygen bond lengths in the formate ion.

THIS QUESTION IS CONTINUED ON THE NEXT PAGE.

Marks
7

What is the molecular geometry of the formate ion?

Write the equilibrium constant expression for Equation 1.

At equilibrium at 25 °C, the amount of formate ion formed from a 0.100 M solution of formic acid is 4.2 %. Calculate the concentration of $H^+(aq)$ in this solution.

Answer:

Calculate the value of the equilibrium constant, K, for Equation 1 at this temperature.

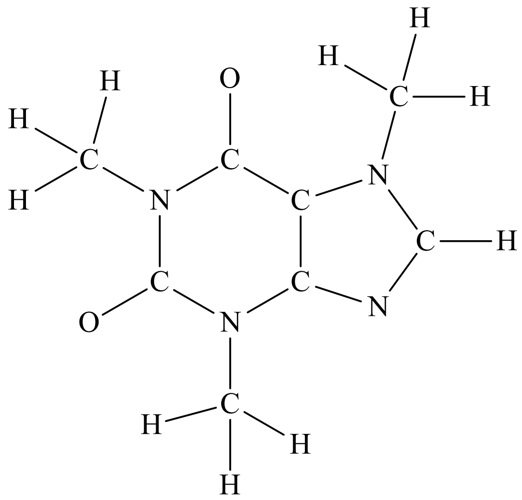
Answer:

Hence calculate the concentration of formate ion in a 0.500 M solution of formic acid.

Answer:

Marks

- By adding double bonds and lone pairs, complete the structural formula of the molecule caffeine below. **2**



- Briefly discuss the relationship between the electron configuration of an element and its position in the Periodic Table. **6**

Carbon and lead are both in Group 14. One is a non-metal and the other is a metal. Outline one physical and one chemical characteristic of a non-metal and a metal and explain the reason for the trend from one to another in Group 14.

	Non-metal	Metal
Physical characteristic		
Chemical characteristic		

Explanation for trend in Group 14

Marks
8

- Rechargeable nickel-cadmium batteries normally operate (discharge) with the following oxidation and reduction half-cell reactions.

  $Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-(aq)$ $E°$ (1) = –0.82 V

  $AlF_6^{3-}(aq) + 3e^- \rightarrow Al(s) + 6F^-(aq)$ $E°$ (2) = –2.07 V

  Write out a balanced overall cell reaction.

Calculate the overall cell potential under standard conditions.

Answer:

A constant current of 3.15 A is measured during the operation of this cell. What would be the change in mass of the aluminium electrode after 10.0 minutes?

Answer:

Write out the overall cell reaction that would occur spontaneously if half-cell (1) were coupled to a standard hydrogen electrode (SHE).

What would be the cell potential for this new cell?

Answer:

Page Total:

Marks

- Combustion of 15.0 g of coal provided sufficient heat to increase the temperature of 7.5 kg of water from 286 K to 298 K. Calculate the amount of heat (in kJ) absorbed by the water. The heat capacity of water, $C_p° = 4.2$ J K^{-1} g^{-1}. **3**

Answer:

Assuming that coal is pure carbon, calculate the heat of combustion (in kJ mol^{-1}) of the coal.

Answer:

- The standard enthalpy of formation of SO_2(g) is the enthalpy change that accompanies which reaction? **3**

Calculate the standard enthalpy of formation of SO_2(g) given the following data.

$SO_2(g) + {}^1/_2O_2(g) \rightarrow SO_3(g)$ $\Delta H = –99$ kJ mol^{-1}

$S(s) + {}^3/_2O_2(g) \rightarrow SO_3(g)$ $\Delta H = –396$ kJ mol^{-1}

Answer:

Marks

- The standard heat of formation of $ClF_3(g)$ is –159 kJ mol^{-1}. Use the bond enthalpies below to calculate the average Cl–F bond enthalpy in $ClF_3(g)$. **4**

Bond	Cl–Cl	F–F
Bond enthalpy / kJ mol^{-1}	243	158

Answer:

Explain why this number is different from the average Cl–F bond enthalpy estimated for $ClF_5(g)$ of 151 kJ mol^{-1}.

- Explain the observation that the boiling point of ethanol is much higher than that of dimethyl ether despite these compounds having the same molar mass. **1**

compound	formula	boiling point / °C
ethanol	CH_3CH_2OH	78.3
dimethyl ether	CH_3OCH_3	–22.0

Page Total:

CHEM1001 – FUNDAMENTALS OF 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 = 1.013 bar	1 Ci = 3.70×10^{10} Bq
0 °C = 273 K	1 Hz = 1 s^{-1}
1 L = 10^{-3} m^3	1 tonne = 10^3 kg
1 Å = 10^{-10} m	1 W = 1 J s^{-1}
1 eV = 1.602×10^{-19} J	1 J = 1 kg m^2 s^{-2}

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
10^{12}	tera	T

CHEM1001 – FUNDAMENTALS OF 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
$Cl_2 + 2e^- \rightarrow 2Cl^-(aq)$	+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
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O$	+0.96
$Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$	+0.92
$NO_3^-(aq) + 10H^+(aq) + 8e^- \rightarrow NH_4^+(aq) + 3H_2O$	+0.88
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+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
$BiO^+(aq) + 2H^+(aq) + 3e^- \rightarrow Bi(s) + H_2O$	+0.32
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0 (by definition)
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	–0.04
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.126
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.136
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	–0.24
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	–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

CHEM1001 – FUNDAMENTALS OF CHEMISTRY 1A

Useful formulas

Quantum Chemistry $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $E = -Z^2 E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$ $T\lambda = 2.898 \times 10^6$ K nm	**Electrochemistry** $\Delta G° = -nFE°$ $Moles\ of\ e^- = It/F$ $E = E° - (RT/nF) \times \ln Q$ $E° = (RT/nF) \times \ln K$ $E = E° - \frac{0.0592}{n} \log Q$ (at 25 °C)
Acids and Bases $pH = -\log[H^+]$ $pK_w = pH + pOH = 14.00$ $pK_w = pK_a + pK_b = 14.00$ $pH = pK_a + \log\{[A^-] / [HA]\}$	**Gas Laws** $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$ $E_k = \frac{1}{2}mv^2$
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** $t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_0 - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
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** $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT \ln Q$ $\Delta G° = -RT \ln K$ $\Delta_{univ}S° = R \ln K$ $K_p = K_c\left(\frac{RT}{100}\right)^{\Delta n}$
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** [263]	105 DUBNIUM **Db** [268]	106 SEABORGIUM **Sg** [271]	107 BOHRIUM **Bh** [274]	108 HASSIUM **Hs** [270]	109 MEITNERIUM **Mt** [278]	110 DARMSTADTIUM **Ds** [281]	111 ROENTGENIUM **Rg** [281]	112 COPERNICIUM **Cn** [285]		114 FLEROVIUM **Fl** [289]		116 LIVERMORIUM **Lv** [293]		

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]