Topics in the June 2013 Exam Paper for CHEM1001

Click on the links for resources on each topic.

2013-J-2:

- Lewis Model of Bonding
- VSEPR

2013-J-3:

- Lewis Model of Bonding
- Elements and Atoms

2013-J-4:

- Stoichiometry
- Gas Laws
- Molecules and Ions
- The Periodic Table

2013-J-5:

- Elements and Atoms
- Molecules and Ions
- Chemical Equations
- The Periodic Table

2013-J-6:

- Stoichiometry

2013-J-7:

- Lewis Model of Bonding
- Types of Intermolecular Forces

2013-J-8:

- Batteries and Corrosion
- Electrolytic Cells

2013-J-9:

- Gas Laws
- Thermochemistry

2013-J-10:

- Chemical Equilibrium

2013-J-11:

- Types of Intermolecular Forces

2013-J-12:

- Thermochemistry
- First Law of Thermodynamics

2201(a)

THE UNIVERSITY OF SYDNEY

FUNDAMENTALS OF CHEMISTRY 1A - CHEM1001

FIRST SEMESTER EXAMINATION

CONFIDENTIAL

JUNE 2013 **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 10, 15, 20 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
11	10			
12	7			
13	7			
14	6			
16	7			
17	5			
18	9			
19	4			
21	8			
22	3			
23	6			
Total	72			
Check Total				

Marks 10

- Complete the following table, including resonance structures where appropriate. The central atom is underlined.

Species	Lewis structure	Molecular geometry	Is the species polar?
$\underline{N}F_3$			
$\underline{S}O_2$			
$\underline{Cl}F_5$			
$\underline{B}H_3$			

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

• Explain the term ‘resonance structures’ and give an example.	**Marks** **2**

• Explain why stable compounds of oxygen have 8 electrons in the valence shell, but compounds of sulfur may have 8, 10 or 12 electrons in their valence shell.	**2**

• In the spaces provided, briefly explain the meaning of the following terms.	**3**
Valence electrons	
Polar bond	
Intensive properties	

Marks

- In an experiment, 5.0 g of magnesium was dissolved in excess hydrochloric acid to give magnesium ions and hydrogen gas. Write a balanced equation for the reaction that occurred. **4**

What amount of hydrogen gas (in mol) is produced in the reaction?

Answer:

What volume would the hydrogen occupy at 25 °C and 100.0 kPa pressure?

Answer:

- Silicon and carbon are both in Group 14 and form dioxides. Carbon dioxide is a gas at room temperature while silicon dioxide (sand) is a solid with a high melting point. Describe the bonding in these two materials and explain the differences in properties they show. **3**

Marks

- Complete the following table by filling in the compound name or formula as required. **2**

Name	Formula
lead(II) chloride	
dinitrogen trioxide	
	Na_2SO_4
	SF_6

- In the Periodic Table given, hydrogen is placed at the top of Group 1. List reasons for and against placing hydrogen in this position. **4**

For:

Against:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks 7

- A 0.060 M solution of aluminium nitrate and a 0.080 M solution of potassium phosphate are prepared by dissolving $Al(NO_3)_3$ and K_3PO_4 in water. Write the ionic equations for these two dissolutions reactions.

Dissolution of $Al(NO_3)_3$	
Dissolution of K_3PO_4	

If these solutions are combined, aluminium phosphate precipitates. Write the ionic equation for the precipitation reaction.

100.0 mL of the aluminium nitrate solution is added to 50.0 mL of the potassium phosphate solution. What amount (in mol) of aluminium phosphate precipitates?

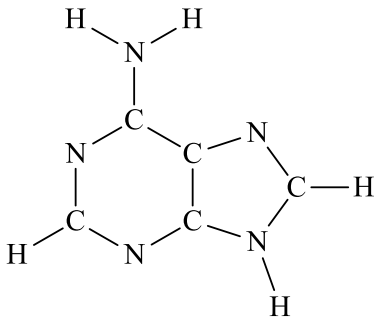
Answer:

What is the final concentration of aluminium ions remaining in solution after the precipitation?

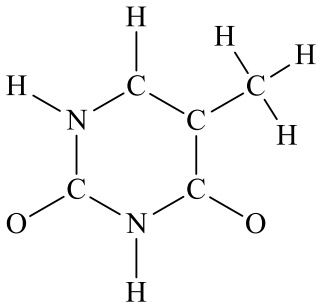
Answer:

Marks 5

- By adding double bonds and lone pairs, complete the structural formulae of the nitrogen bases adenine and thymine below.



adenine



thymine

In DNA, these two molecules interact through two hydrogen bonds. Redraw the structures below showing the alignment of the two molecules that allows this to occur and clearly show the hydrogen bonds.

Marks 9

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

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

$NiO(OH)(s) + H_2O(l) + e^- \rightarrow Ni(OH)_2(s) + OH^-(aq)$ $\quad E° = 0.60$ V

Write out a balanced overall cell reaction.

Calculate the overall cell potential.

Answer:

Using your balanced cell reaction, briefly explain why the cell potential does not change as the battery discharges itself.

Write out the balanced overall reaction that occurs when this battery is being recharged.

A current of 2.75 A is measured during recharging with an external potential of 2.0 V. After 5.00 minutes charging, how many moles of Cd(s) will be redeposited?

Answer:

Marks 4

- A certain mixture of gases containing 0.24 mol of He, 0.53 mol of N_2 and 0.05 mol of Ne is placed in a container with a piston that maintains it at a total pressure of 1.0 atm. This gas mixture is now heated from its initial temperature of 290 K to 370 K by passing 2.08 kJ of energy into it.
  Calculate the volume occupied by the gas at 370 K.

Answer:

Calculate the heat capacity of the gas mixture (in J K^{-1} mol^{-1}).

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks 8

- Nitrogen and acetylene gases react to form hydrogen cyanide according to the reaction

$$N_2(g) + C_2H_2(g) \rightleftharpoons 2HCN(g) \quad K_c = 2.3 \times 10^{-4} \text{ at } 300\ ^\circ C$$

Write out the equilibrium constant expression for K_c for this reaction as shown above.

The value of K_p for this reaction at 300 °C is also 2.3×10^{-4}. Why are the values of K_p and K_c the same for this reaction?

Write a balanced equation and calculate the value of the equilibrium constant K_c' for the formation of 1.0 mol of hydrogen cyanide gas from nitrogen and acetylene gases.

Answer:

What is the equilibrium concentration of HCN(g) if nitrogen and acetylene are mixed so that both are at starting concentrations of 1.0 mol L^{-1}?

Answer:

• The boiling point of NH_3 is –33 °C and that of HF is +20 °C. Explain this difference in terms of the strengths of the intermolecular forces between these molecules.	**Marks 3**

Explain why the boiling point of water (100 °C) is higher than both HF and NH_3.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

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).

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

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $\Delta H° = -114.1$ 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:

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
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
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

$\Delta G^\circ = -nFE^\circ$

Moles of $e^- = It/F$

$E = E^\circ - (RT/nF) \times \ln Q$

$E^\circ = (RT/nF) \times \ln K$

$E = E^\circ - \dfrac{0.0592}{n} \log Q$ (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

$t_{1/2} = \ln 2/\lambda$

$A = \lambda N$

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

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

Kinetics

$t_{1/2} = \ln 2/k$

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

$\ln[A] = \ln[A]_0 - kt$

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

Colligative Properties & Solutions

$\Pi = cRT$

$P_{solution} = X_{solvent} \times P^\circ_{solvent}$

$c = kp$

$\Delta T_f = K_f m$

$\Delta T_b = K_b m$

Thermodynamics & Equilibrium

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$\Delta G = \Delta G^\circ + RT \ln Q$

$\Delta G^\circ = -RT \ln K$

$\Delta_{univ} S^\circ = R \ln K$

$K_p = K_c\left(\dfrac{RT}{100}\right)^{\Delta n}$

Miscellaneous

$A = -\log \dfrac{I}{I_0}$

$A = \varepsilon cl$

$E = -A \dfrac{e^2}{4\pi\varepsilon_0 r} N_A$

Mathematics

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

$\ln x = 2.303 \log x$

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]