22/15(a)

The University of Sydney

CHEM1109 - CHEMISTRY 1 LIFE SCIENCES B

SECOND SEMESTER EXAMINATION

CONFIDENTIAL

NOVEMBER 2007 **TIME ALLOWED: THREE HOURS**

GIVE THE FOLLOWING INFORMATION IN BLOCK LETTERS

FAMILY NAME		**SID NUMBER**	
OTHER NAMES		**TABLE NUMBER**	

OFFICIAL USE ONLY

Multiple choice section

	Marks	
Pages	Max	Gained
2-10	33	

INSTRUCTIONS TO CANDIDATES

- All questions are to be attempted. There are 21 pages of examinable material.
- Complete 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 question of the short answer section 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 sheet.
- Pages 17 and 24 are for rough working only.

Short answer section

Page	Marks Max	Gained		Marker
11	7			
12	7			
13	5			
14	3			
15	6			
16	6			
18	6			
19	6			
20	6			
21	5			
22	5			
23	5			
Total	67			

	Marks
• A solution of 2.00 M NaOH (50.0 mL) at 44.9 ºC is added to a constant pressure ("coffee cup") calorimeter containing 250.0 mL of 0.70 M HNO_3 at 21.5 ºC. The final temperature of the solution is 29.9 ºC. Calculate the enthalpy of neutralisation of $OH^-(aq)$ and $H^+(aq)$ in kJ mol^{-1}. Assume the density of these solutions is 1.000 g mL^{-1} and the specific heat capacity of the solutions is 4.184 J K^{-1} g^{-1}.	**4**
Answer:	
Calculate the pH in the combined solution in the calorimeter at 21.5 ºC.	
Answer:	
• A 300.0 mL solution of HCl has a pH of 1.22. Given that the pK_a of iodic acid, HIO_3, is 0.79, how many moles of sodium iodate, $NaIO_3$, would need to be added to this solution to raise its pH to 2.00?	**3**
Answer:	

Marks 4

- Acetylene, C_2H_2, can be produced by reacting calcium carbide, CaC_2, with water:

$$CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + C_2H_2(g)$$

A 1.000 g sample of CaC_2 is placed in a sealed vessel that contains 250.0 mL of $H_2O(l)$ and 250.0 mL of $N_2(g)$ at 1.000 atm, and allowed to react completely with the water. The final pressure in the sealed vessel at 22.0 ºC is 2.537 atm. Determine the vapour pressure of water in the sealed vessel at 22.0 ºC. Give your answer in mmHg. Ignore any change in the volume of the water.

Answer:

The solubility of acetylene in water at 22.0 ºC is small. If the temperature were raised, would you expect this solubility to increase or decrease?

3

- Draw all possible stereoisomers of the complex ion $[CoCl_2(en)_2]^+$. Label each as *cis* or *trans*.

Marks 5

- Consider the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

  $\Delta H° = -198.4$ kJ mol^{-1} and $\Delta S° = -187.9$ J K^{-1} mol^{-1} at 25 °C.

  Show that this reaction is spontaneous at 25 °C.

If the volume of the reaction system is increased at 25 °C, in which direction will the reaction move?

Calculate the value of the equilibrium constant, K, at 25 °C.

$K =$

Assuming $\Delta H°$ and $\Delta S°$ are independent of temperature, in which temperature range is the reaction non-spontaneous?

Answer:

Marks 3

- Ammonium perchlorate mixed with powdered aluminium powers the space shuttle booster rockets:

$$2NH_4ClO_4(s) + 2Al(s) \rightarrow Al_2O_3(s) + 2HCl(g) + 2NO(g) + 3H_2O(g)$$

Given the following thermochemical data, how much heat would be released per gram of Al(s)?

ΔH_f^o ($H_2O(l)$) = –285.1 kJ mol^{-1} ΔH_f^o ($Al_2O_3(s)$) = –1669.8 kJ mol^{-1}

ΔH_f^o ($NO(g)$) = 90.4 kJ mol^{-1} ΔH_f^o ($NH_4ClO_4(s)$) = –290.6 kJ mol^{-1}

ΔH_f^o ($HCl(g)$) = –92.3 kJ mol^{-1} ΔH_{vap}^o (H_2O) = 44.1 kJ mol^{-1}

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

	Marks
• Lysozyme is an enzyme that breaks down bacterial cell walls. A solution containing 0.150 g of this enzyme in 210 mL of solution has an osmotic pressure of 0.00125 atm at 25 ^{o}C. What is the molar mass of lysozyme?	**3**
Answer:	
• What mass of ethylene glycol, $HOCH_2CH_2OH$, is required to lower the freezing point of 1.00 L of water to –10.0 °C? The freezing point depression constant of water is 1.86 °C kg mol^{-1}. Assume the density of water is 1.00 g mL^{-1} at 0 °C.	**3**
Answer:	

Marks 6

- The first step in the metabolism of glucose in biological systems is the addition of a phosphate group in a dehydration-condensation reaction:

$$\text{glucose(aq)} + H_2PO_4^-\text{(aq)} \rightleftharpoons [\text{glucose phosphate}]^-\text{(aq)} + H_2O\text{(l)}$$

The free energy change associated with this reaction is $\Delta G° = 13.8$ kJ mol^{-1}. The reaction is driven forwards by harnessing the free energy associated with the hydrolysis of adenosine triphosphate, ATP^{4-}, to adenosine diphosphate, ADP^{3-}:

$$ATP^{4-}\text{(aq)} + H_2O\text{(l)} \rightleftharpoons ADP^{3-}\text{(aq)} + H_2PO_4^-\text{(aq)} \qquad \Delta G° = -30.5 \text{ kJ mol}^{-1}$$

The overall reaction is thus:

$$\text{glucose(aq)} + ATP^{4-}\text{(aq)} \rightleftharpoons [\text{glucose phosphate}]^-\text{(aq)} + ADP^{3-}\text{(aq)}$$

Calculate the equilibrium constant associated with this overall reaction at body temperature (37 ºC).

Answer:

This overall equilibrium reaction is investigated by adding 0.0100 mol of ATP^{4-} to a flask containing 175 mL of a 0.0500 M aqueous solution of glucose at 37 ºC. What percentage of the ATP^{4-} will have been consumed when the system reaches equilibrium?

Answer:

Suggest two simple ways of further reducing the remaining percentage of ATP^{4-}.

Marks

- Zinc sulfate (8.07 g) is dissolved in 1.00 L of a 1.00 M solution of KCN. Write the chemical equation for the formation of the aqueous ion $[Zn(CN)_4]^{2-}$.

4

Calculate the concentration of $Zn^{2+}(aq)$ in solution at equilibrium. Ignore any change in volume upon addition of the salt. K_{stab} of $[Zn(CN)_4]^{2-} = 4.2 \times 10^{19}\ M^{-4}$.

Answer:

Name the complex ion.

- The half life of the radioactive isotope ^{16}N is 7.13 s. Calculate how long it takes to reduce the radioactivity of a given sample to 71.6% of the initial value.

2

Answer:

Marks 6

- The solubility product constant of AgCl is $K_{sp} = 1.8 \times 10^{-10}\ M^2$. Using the relevant electrode potentials found on the data page, calculate the reduction potential at 298 K of a half-cell formed by:
  (a) an Ag electrode immersed in a saturated solution of AgCl.

Answer:

(b) an Ag electrode immersed in a 0.5 M solution of KCl containing some AgCl precipitate.

Answer:

Each of these half-cells is connected to a standard Cu^{2+}(1 M)/Cu(s) half-cell. In which half-cell, (a) or (b), will clear evidence of a reaction be seen? Describe the change(s) observed.

	Marks
• Describe how the addition of an electrolyte can alter the state of a colloidal dispersion.	**2**
• An aqueous solution of $CuSO_4$ is electrolysed with a current of 1.00 A for 60 minutes. Calculate the mass of the products that are formed at the two electrodes.	**4**

	Marks
• The pH of a solution can be controlled by adding small amounts of gaseous HCl. Assuming no change in volume, calculate what the pH of the solution must be to just dissolve 1.00 g of NiS suspended in 1.0 L of water. Data: $H_2S(aq) \rightleftharpoons 2H^+(aq) + S^{2-}(aq)$ $K = 1.1 \times 10^{-20}\ M^2$ $K_{sp}(NiS) = 1.0 \times 10^{-22}\ M^2$	**5**

pH =

• A galvanic cell consists of a Ni^{2+}/Ni half cell with $[Ni^{2+}]$ = 1.00 M, and a Ag^{+}/Ag half cell with $[Ag^{+}]$ = 1.00 M. Calculate the electromotive force of the cell at 25 °C.	**Marks 5**
	Answer:
Calculate the equilibrium constant of the reaction at 25 °C.	
	Answer:
Calculate the standard free energy change of the reaction at 25 °C.	
	Answer:
Is the reaction spontaneous? Give reasons for your answer.	
Express the overall reaction in the shorthand voltaic cell notation.	

Marks 5

- Phosgene is a toxic gas prepared by the reaction of carbon monoxide with chlorine:

$$CO(g) + Cl_2(g) \rightarrow COCl_2(g)$$

The following data were obtained in a kinetics study of its formation at 150 °C.

Experiment	initial [CO] (M)	initial [Cl_2] (M)	Initial rate ($M\ s^{-1}$)
1	1.00	0.100	1.29×10^{-29}
2	0.100	0.100	1.33×10^{-30}
3	0.100	1.00	1.30×10^{-29}
4	0.100	0.0100	1.32×10^{-31}

Determine the rate law for the reaction.

Calculate the value of the rate constant at 150 °C.

Answer:

Calculate the rate of appearance of phosgene when [CO] = [Cl_2] = 1.3 M.

Answer:

CHEM1109 - CHEMISTRY 1 LIFE SCIENCES B

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

CHEM1109 - CHEMISTRY 1 LIFE SCIENCES B

Standard Reduction Potentials, *E*°

Reaction	*E*° / V
$S_2O_8^{2-} + 2e^- \rightarrow 2SO_4^{2-}$	+2.01
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+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
$Br_2 + 2e^- \rightarrow 2Br^-(aq)$	+1.10
$MnO_2(s) + 4H^+(aq) + e^- \rightarrow Mn^{3+} + 2H_2O$	+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
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–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

CHEM1109 - CHEMISTRY 1 LIFE SCIENCES B

Useful formulas

Quantum Chemistry

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

$\lambda = h/mv$

$4.5k_BT = hc/\lambda$

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

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

$q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$

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

$PV = nRT$

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

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

$t_{½} = \ln 2/k$

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

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

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

Radioactivity

$t_{½} = \ln 2/\lambda$

$A = \lambda N$

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

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

Thermodynamics & Equilibrium

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta G = \Delta G° + RT \ln Q$

$\Delta G° = -RT \ln K$

$K_p = K_c (RT)^{\Delta n}$

Miscellaneous

$A = -\log_{10} \frac{I}{I_0}$

$A = \varepsilon cl$

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

Mathematics

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

$\ln x = 2.303 \log x$

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]							

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]