

Topics in the November 2014 Exam Paper for CHEM1612

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- [Complexes](#)
- [Chemical Equilibrium](#)
- [Chemical Kinetics](#)
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- [Redox Reactions and Introduction to Electrochemistry](#)

2014-N-14:

- Chemical Kinetics

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THE UNIVERSITY OF
SYDNEY

SEAT NUMBER:

STUDENT ID:

SURNAME:

GIVEN NAMES:

CHEM1612
Chemistry B (Pharmacy)

Final Examination
Semester 2, 2014

Time Allowed: Three hours + 10 minutes reading time

This examination paper consists of 24 pages

INSTRUCTIONS TO CANDIDATES

1. This is a closed book exam.
 2. A simple calculator (programmable versions and PDA's not allowed) may be taken into the exam room.
- | Make | Model |
|------|-------|
| | |
3. The total score for this paper is 100. The possible score per page is shown in the adjacent table.
 4. The paper comprises 30 multiple choice questions and 13 pages of short answer questions.
ANSWER ALL QUESTIONS.
 5. Follow the instructions on page 2 to record your answers to the multiple choice questions. Use a dark lead pencil so that you can erase errors made on the computer sheet.
 6. Answer all short answer questions in the spaces provided on this question paper. Credit may not be given where there is insufficient evidence of the working required to obtain the solution.
 7. Take care to write legibly. Write your final answers in ink, not pencil.
 8. 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.

Page(s)	Marks		Marker
	Max	Gained	
2-10	30		MCQ
11	6		
12	7		
13	4		
14	3		
15	3		
16	7		
17	2		
18	4		
19	8		
20	7		
21	7		
22	8		
23	4		
Total	100		
Check Total			

<ul style="list-style-type: none">Explain the following terms or concepts.	Marks 3
Lewis base	
Le Châtelier's principle	
Heterogeneous catalysis	
<ul style="list-style-type: none">A bar of hot iron with a mass of 1.000 kg and a temperature of 100.00 °C is plunged into an insulated tank of water. The mass of water was 2.000 kg and its initial temperature was 25.00 °C. What will the temperature of the resulting system be when it has reached equilibrium? The specific heat capacities of water and iron are 4.184 J g⁻¹ K⁻¹ and 0.4498 J g⁻¹ K⁻¹, respectively.	3
Answer:	

- A mass of 1.250 g of benzoic acid, $C_7H_6O_2$, underwent combustion in a bomb calorimeter. The heat of combustion of benzoic acid is $-3226 \text{ kJ mol}^{-1}$. What is the change in internal energy during this reaction?

Marks
4

Answer:

If the heat capacity of the calorimeter is 10.134 kJ K^{-1} , calculate the temperature change that should have occurred in the apparatus.

Answer:

- Phenylketonuria is an inherited disorder in which phenylacetic acid, $C_6H_5CH_2COOH$, (simplified here to HPAC) accumulates in the blood. A study of the acid shows that the pH of a 0.12 M HPAC solution is 2.60. What is the pK_a of phenylacetic acid?

3

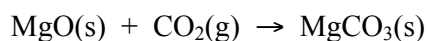
Answer:

- The freezing point of a sample of seawater is measured as $-2.15\text{ }^{\circ}\text{C}$ at 1 atm pressure. Assuming that the concentrations of other solutes are negligible, determine the molality (in mol kg^{-1}) of NaCl in this sample. The molal freezing point depression constant for H_2O is $1.86\text{ }^{\circ}\text{C kg mol}^{-1}$.

Marks
3

Answer:

- What is the value of the enthalpy change for the following reaction?



Data:	Compound	MgO(s)	CO ₂ (g)	MgCO ₃ (s)
	$\Delta_f H^{\circ} / \text{kJ mol}^{-1}$	-602	-394	-1096

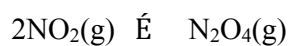
1

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Page Total:

- Consider the following reaction and associated thermochemical data?



Data:	Compound	$\text{NO}_2(\text{g})$	$\text{N}_2\text{O}_4(\text{g})$
	$\Delta_f H^\circ / \text{kJ mol}^{-1}$	33	9
	$S^\circ / \text{J K}^{-1} \text{mol}^{-1}$	240	304

What is the expression for the equilibrium constant, K_c , for this reaction?

What are the values of ΔH° and ΔS° for the reaction?

$\Delta H^\circ =$

$\Delta S^\circ =$

What is the value of ΔG° for the reaction at 298 K?

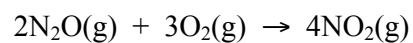
$\Delta G^\circ =$

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks
3

Page Total:

- Consider the following reaction:



Calculate ΔG° for this reaction given the following data.



Marks
3

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- A sample of hydrofluoric acid (0.10 M, 25.0 mL) is titrated with 0.10 M NaOH. The pK_a of hydrofluoric acid, HF, is 3.17. Calculate the pH at the following four points.

Marks
7

before any NaOH is added

pH =

when half of the HF has been neutralised

pH =

at the equivalence point

pH =

after the addition of 37.5 mL of NaOH

pH =

THIS QUESTION CONTINUES ON THE NEXT PAGE.

Page Total:

Sketch the titration curve.

Marks
2

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Page Total:

- At 700 °C, hydrogen and iodine react according to the following equation.

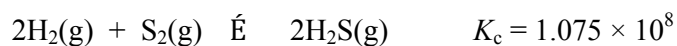


If 0.250 mol of HI(g) is introduced into a 2.00 L flask at 700 °C, what will be the concentration of I₂(g) at equilibrium?

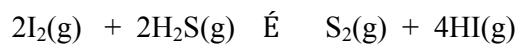
Marks
4

Answer:

Hydrogen also reacts with sulfur at 700 °C:



Determine K_c for the following overall equilibrium reaction at 700 °C.



Answer:

Page Total:

- Write balanced nuclear equations for the following changes.

Marks
4

Electron capture by ^{37}Ar

Positron emission by ^{93}Ru

Beta particle emission by ^{42}K

Alpha particle emission by ^{251}Cf

- Give the oxidation number of the indicated atom in the following compounds.

2

Compound	Atom	Oxidation number
HNO_2	N	
NI_3	N	
$[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{SO}_4$	Co	
$\text{K}_3[\text{CrCl}_6]$	Cr	

- Write down the formulas for the following compounds.

2

Compound	Formula
hexaaquacobalt(II) carbonate	
tetraamminecopper(II) sulfate	
ammonium hexafluoridoferrate(III)	
potassium hexacyanidomanganate(II)	

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Page Total:

- The K_{sp} of AgBr is 5.0×10^{-13} . The K_{stab} of $[\text{Ag}(\text{S}_2\text{O}_3)_2]^{3-}$ is 4.7×10^{13} . Calculate the value of the equilibrium constant for the dissolution of AgBr in $\text{Na}_2\text{S}_2\text{O}_3$ solution.

Marks
7

Answer:

Calculate the solubility of AgBr in 2.0 M $\text{Na}_2\text{S}_2\text{O}_3$.

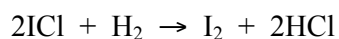
Answer:

The K_{stab} for $[\text{Ag}(\text{S}_2\text{O}_3)_2]^{3-}$ is much greater than the K_{stab} for $[\text{Ag}(\text{NH}_3)_2]^+$. Explain why this is so.

<ul style="list-style-type: none">• Draw sketches of a detergent micelle, a lipid vesicle and a water-in-oil microemulsion.	Marks 3
<ul style="list-style-type: none">• In the electrolytic production of Al, what mass of Al can be deposited in 2.00 hours by a current of 1.8 A?	2
<div>Answer:</div>	
<ul style="list-style-type: none">• What products would you expect at the anode and the cathode on electrolysis of a 1 M aqueous solution of NiI_2? Explain your answers.	2

<ul style="list-style-type: none">An electrochemical cell is consists of 1.0 L half-cells of Fe/Fe²⁺ and Cd/Cd²⁺ with the following initial concentrations: [Fe²⁺] = 0.800 M, [Cd²⁺] = 0.200 M. <p>What is the initial E_{cell} at 25 °C?</p>		Marks 8
Answer:		
What is E_{cell} when [Cd ²⁺] reaches 0.15 M?		
Answer:		
What is [Cd ²⁺] when E_{cell} reaches 0.015 V?		
Answer:		
What are the equilibrium concentrations of both ions?		
[Cd ²⁺] =	[Fe ²⁺] =	

- At a certain temperature the following data were collected for the reaction shown.



Experiment	Initial [ICl] (mol L ⁻¹)	Initial [H ₂] (mol L ⁻¹)	Rate of formation of [I ₂] (mol L ⁻¹ s ⁻¹)
1	0.10	0.10	0.0015
2	0.20	0.10	0.0030
3	0.10	0.050	0.00075

Determine the rate law for the reaction.

What is the value of the rate constant?

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks
4

THIS PAGE IS FOR ROUGH WORKING ONLY.

DATA SHEET*Physical constants*

Avogadro constant, $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

Faraday constant, $F = 96485 \text{ C mol}^{-1}$

Planck constant, $h = 6.626 \times 10^{-34} \text{ J s}$

Speed of light in vacuum, $c = 2.998 \times 10^8 \text{ m s}^{-1}$

Rydberg constant, $E_R = 2.18 \times 10^{-18} \text{ J}$

Boltzmann constant, $k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$

Permittivity of a vacuum, $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$

Gas constant, $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
 $= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$

Charge of electron, $e = 1.602 \times 10^{-19} \text{ C}$

Mass of electron, $m_e = 9.1094 \times 10^{-31} \text{ kg}$

Mass of proton, $m_p = 1.6726 \times 10^{-27} \text{ kg}$

Mass of neutron, $m_n = 1.6749 \times 10^{-27} \text{ kg}$

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 m³

1 Å = 10⁻¹⁰ m

1 eV = 1.602 × 10⁻¹⁹ J

1 Ci = 3.70 × 10¹⁰ Bq

1 Hz = 1 s⁻¹

1 tonne = 10³ 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

Standard Reduction Potentials, E°

Reaction	E° / V
$\text{Co}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Co}^{2+}(\text{aq})$	+1.82
$\text{Ce}^{4+}(\text{aq}) + \text{e}^- \rightarrow \text{Ce}^{3+}(\text{aq})$	+1.72
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}$	+1.51
$\text{Au}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Au}(\text{s})$	+1.50
$\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2 + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$	+1.23 (+0.82 at pH = 7)
$\text{Pt}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pt}(\text{s})$	+1.18
$\text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{Mn}^{3+} + 2\text{H}_2\text{O}$	+0.96
$\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 3\text{e}^- \rightarrow \text{NO}(\text{g}) + 2\text{H}_2\text{O}$	+0.96
$\text{Pd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pd}(\text{s})$	+0.92
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{I}_2(\text{aq}) + 2\text{e}^- \rightarrow 2\text{I}^-(\text{aq})$	+0.62
$\text{Cu}^+(\text{aq}) + \text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.53
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{BiO}^+(\text{aq}) + 2\text{H}^+(\text{aq}) + 3\text{e}^- \rightarrow \text{Bi}(\text{s}) + \text{H}_2\text{O}$	+0.32
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}^{2+}(\text{aq})$	+0.15
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0 (by definition)
$\text{Fe}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.04
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$	-0.24
$\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cd}(\text{s})$	-0.40
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.44
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.74
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83 (-0.41 at pH = 7)
$\text{Cr}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.89
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Al}(\text{s})$	-1.68
$\text{Sc}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Sc}(\text{s})$	-2.09
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mg}(\text{s})$	-2.36
$\text{Na}^+(\text{aq}) + \text{e}^- \rightarrow \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ca}(\text{s})$	-2.87
$\text{Li}^+(\text{aq}) + \text{e}^- \rightarrow \text{Li}(\text{s})$	-3.04

Useful formulas

Thermodynamics & Equilibrium $\Delta U = q + w = q - p\Delta V$ $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G = \Delta G^\circ + RT \ln Q$ $\Delta G^\circ = -RT \ln K$ $\Delta_{\text{univ}} S^\circ = R \ln K$ $\ln \frac{K_2}{K_1} = \frac{-\Delta H^\circ}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$	Electrochemistry $\Delta G^\circ = -nFE^\circ$ <i>Moles of e^- = It/F</i> $E = E^\circ - (RT/nF) \times 2.303 \log Q$ $= E^\circ - (RT/nF) \times \ln Q$ $E^\circ = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E^\circ - \frac{0.0592}{n} \log Q$ (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 $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$ $E_k = \frac{1}{2}mv^2$
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 $t_{1/2} = \ln 2 / k$ $k = Ae^{-E_a/RT}$ $\ln[A] = \ln[A]_0 - kt$ $\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$
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 = $4\pi r^2$ Volume of sphere = $\frac{4}{3} \pi r^3$	Quantum Chemistry $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $E = -Z^2 E_R (1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$ $T\lambda = 2.898 \times 10^6 \text{ K nm}$
Miscellaneous $A = -\log \frac{I}{I_0}$ $A = \epsilon cl$ $E = -A \frac{e^2}{4\pi\epsilon_0 r} N_A$	Colligative Properties & Solutions $\Pi = cRT$ $P_{\text{solution}} = X_{\text{solvent}} \times P^\circ_{\text{solvent}}$ $c = kp$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$

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																
11 SODIUM Na 22.99	12 MAGNESIUM Mg 24.31																
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 YTRIUM Y 88.91	40 ZIRCONIUM Zr 91.22	41 NIOBIUM Nb 92.91	42 MOLYBDENUM Mo 95.94	43 TECHNETIUM Tc [98.91]	44 RHUTHENIUM 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 RHEINIUM 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 REITHERIUM Rf [261]	105 DUBNIUM Db [262]	106 SEABORGIUM Sg [266]	107 BOHRIUM Bh [262]	108 HASSIUM Hs [265]	109 MEITNERIUM Mt [266]	110 DARMSTADIUM Ds [271]	111 ROENTGIUM Rg [272]	112 COPIERNICIUM Cn [283]		114 FLEROVIUM Fl [289]		116 LIVERMORIUM Lv [293]		

LANTHANOIDS

57	LANTHANUM	58	CEBRIUM	59	PRASEODYMIUM	60	NEODYMIUM	61	PROMETHIUM	62	SAMARIUM	63	EUROPIUM	64	GADOLINIUM	65	TERBIUM	66	DYSPROSIUM	67	HOIMIUM	68	ERBIUM	69	THULIUM	70	YTERBIUM	71	LUTETIUM
La		Ce		Pr		Nd		Pm		Sm		Eu		Gd		Tb		Dy		Ho		Er		Tm		Yb		Lu	
138.91		140.12		140.91		144.24		[144.9]		150.4		151.96		157.25		158.93		162.50		164.93		167.26		168.93		173.04		174.97	
89	ACTINIUM	90	THORIUM	91	PROTACTINIUM	92	URANIUM	93	NEPTUNIUM	94	PLUTONIUM	95	AMERICIUM	96	CEURIUM	97	BERKELIUM	98	CALIFORNIUM	99	EINSTEINIUM	100	FERMIUM	101	MENDELIUM	102	NOBELIUM	103	LAWRENCIUM
Ac		Th		Pa		U		Np		Pu		Am		Cm		Bk		Cf		Es		Fm		Md		No		Lr	
[227.0]		232.04		[231.0]		238.03		[237.0]		[239.1]		[243.1]		[247.1]		[247.1]		[252.1]		[252.1]		[257.1]		[256.1]		[259.1]		[260.1]	

ACTINOIDS