Chemistry 1A03/1E03 **VERSION 1**

DURATION OF EXAMINATION: 3 hours
INSTRUCTORS: M. Austen, J. Barbier, R. Dumont, P. Lock, C. Paige
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THIS EXAMINATION CONTAINS 24 NUMBERED PAGES. THERE ARE **36** MULTIPLE-CHOICE QUESTIONS appearing on pages numbered 3 to 20, some useful data are given on page 23 and a periodic table on page 24. Pages 21 and 22 are for rough work. You may tear off the last page to view the periodic table and the data sheet.

Question 1 identifies the version of the test you are writing. Be sure to answer this question correctly. Questions 2 to 29 are each worth 2 marks, questions 30 – 36 are each worth 3 marks; the total marks available are 77. There is **no** additional penalty for incorrect answers.

YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE QUESTION PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

ANSWER ALL QUESTIONS ON THE ANSWER SHEET PROVIDED.
These question sheets must be returned with your answers.
However, no work written on the question sheets will be marked.
Instructions for entering multiple-choice answers are given on page 2.
Select one answer in each question from the answers **(A)** through **(E).**
Your answers to all questions must be entered onto THE ANSWER SHEET IN PENCIL.
Enter one and only one answer for each question.

ONLY CASIO FX 991 ELECTRONIC CALCULATORS MAY BE USED; but they must NOT be transferred between students.
Use of periodic tables, other than the table on page 24, is not allowed.

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Any questions not relevant to Chem 1A03 Fall 2008 have been covered up, to prevent confusion. Please note blank pages when printing. Exam answers will not be posted, but you are welcome to discuss them in WebCT bulletin board or in office hours/help centre.

1. You are writing version 1 of the exam. Please choose bubble 1 (A) for question 1.

Questions 2 - 29 are worth 2 marks each.

2. Which one reaction is **not** an **acid-base** reaction?:

(A) $NaH_2PO_4(aq) + Li_2CO_3(aq) \rightarrow Na^+(aq) + HPO_4^{2-}(aq) + 2\ Li^+(aq) + HCO_3^-(aq)$

(B) $KHCO_3(aq) + KOH(aq) \rightarrow K_2CO_3(aq) + H_2O(l)$

(C) $BaO(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + H_2O(l)$

(D) $CH_3COOH(aq) + H_2O(l) \rightarrow CH_3COO^-(aq) + H_3O^+(aq)$

(E) $Ag(s) + 2\ HNO_3(aq) \rightarrow AgNO_3(aq) + NO_2(g) + H_2O(l)$

3. Consider the following thermochemical data:

$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g) \qquad \Delta H^\circ = -113.0\ kJ$

$\Delta H_f^\circ[NO_2(g)] = 33.9\ kJ/mol$

What is **$\Delta H_f^\circ[NO(g)]$?**

(A) -180.8 kJ/mol

(B) +146.9 kJ/mol

(C) +90.4 kJ/mol

(D) +73.5 kJ/mol

(A) -73.5 kJ/mol

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5. Which of the following statements is **FALSE**?

(A) [He]$2s^2$ is the electron configuration of the ground state of a Be atom.

(B) [Ar]$5s^2$ is the electron configuration of an excited state of a Ca atom.

(C) [He]$2s^2$ $2p^5$ is the electron configuration of the ground state of a F atom

(D) Nitrogen atoms in their ground state are paramagnetic.

(E) Calcium atoms in their ground state are paramagnetic.

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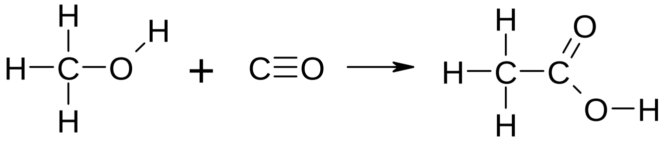
7. Calculate the **enthalpy change** for the reaction $CH_3OH(g) + CO(g) \rightarrow CH_3COOH(g)$,



from the following bond energy (enthalpy) data:

Bond	BE / (kJ/mol)
C-C	347
C-H	413
C-O	358
C=O	745
C≡O	1070
O-H	467

(A) +22 kJ

(B) +336 kJ

(C) -380 kJ

(D) -347 kJ

(E) -22 kJ

8. Which of the following species would have the **shortest Br-O bonds**?

(A) BrO^-

(B) BrO_2^-

(C) BrO_3^-

(D) BrO_4^-

(E) $BrF_2O_2^-$

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9. Which of the following species has the **most negative average formal charge** on the oxygen atoms?

(A) SO_2

(B) PO_4^{3-}

(C) ClO_3^{-}

(D) SeO_3^{2-}

(E) SeO_4^{2-}

10. Identify the **FALSE** statement(s) concerning the dihydrogen phosphate anion, $H_2PO_4^{-}$.

i) The anion has an octahedral shape.

ii) The P atom carries a lone pair of electrons.

iii) Some of the P-O bonds have an average bond order of 5/4.

iv) The anion contains the same number of electrons as the perchlorate anion ClO_4^{-}.

v) The P atom has a formal charge of -1.

(A) i, ii, iii, v

(B) i, iv, v

(C) ii, iii

(D) iii

(E) all

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11. Which one of the following molecular species **is planar**?

(A) IF_4^+

(B) XeF_4

(C) AlF_4^-

(D) ClO_4^-

(E) $SiCl_4$

12. Which of the following molecules have nonzero permanent **dipole moments**?

i) N_2O_4 (each N atom is bonded to two O atoms and an N atom)

ii) CBr_4

iii) NO_2

iv) IF_5

v) SO_3

(A) i

(B) i, ii, v

(C) i, iv

(D) iii, iv

(E) iii, iv, v

13. Which one of the following statements is **FALSE** regarding molecules placed between parallel positively and negatively charged plates?

(A) BF_3 would have no specific orientation with respect to charged plates.

(B) ONF_2 (O and F atoms bonded only to N) would be oriented such that the F atoms are closer to the positive plate.

(C) SF_4 would be oriented such that the S atom is closer to the negative plate.

(D) BrF_3 would have no specific orientation with respect to charged plates.

(E) PCl_5 would have no specific orientation with respect to charged plates.

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15. The melting point of tungsten, 3407°C, is the second highest among the elements. Only that of carbon is higher. The enthalpy of fusion of tungsten is 35.2 kJ/mol. What is the **entropy of fusion** of tungsten?

(A) +9.57 J/mol·K

(B) -9.57 J/mol·K

(C) +10.3 J/mol·K

(D) -10.3 J/mol·K

(E) +104 J/mol·K

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19. Which of the following are **TRUE** statements regarding a **spontaneous reaction** at constant temperature and pressure?

i) $\Delta S_{univ} > 0$

ii) $\Delta G_{sys} < 0$

iii) $\Delta S_{sys} > \Delta H_{sys} / T$

iv) $Q < K$

(A) i, ii

(B) ii, iv

(C) i, ii, iii

(D) i, ii, iv

(E) all

20. The standard Gibbs free energy change at 298K is +7.0 kJ for the reaction

$$2\ Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3\ H_2O(g)$$

What range of water vapour pressures, **$P(H_2O)$,** would make this reaction **spontaneous**?

(A) $P(H_2O) > 0.06$ atm

(B) $P(H_2O) > 0.4$ atm

(C) $P(H_2O) < 0.06$ atm

(D) $P(H_2O) < 0.4$ atm

(E) $P(H_2O) > 1$ atm

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21. For the heterogeneous reaction: $2\ Na(s) + 2\ H_2O(l) \rightleftharpoons 2\ NaOH(aq) + H_2(g)$, the reaction quotient, Q, is written as:

(A) $Q = [Na^+]^2 [OH^-]^2 P(H_2) / [H_2O]^2 [Na]^2$

(B) $Q = [Na^+]^2 [OH^-]^2 P(H_2) / [H_2O]^2$

(C) $Q = [Na^+]^2 [OH^-]^2 P(H_2)$

(D) $Q = P(H_2)$

(E) $Q = 1/ P(H_2)$

22. The following data are for 727 ^{0}C. Calculate the **equilibrium constant,** K, at 727 ^{0}C for the reaction: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ $\Delta H^0_{rxn} = +176.9$ kJ

	S^o / ($J{\cdot}K^{-1}{\cdot}mol^{-1}$)
$CO_2(g)$	+258.7
$CaCO_3(s)$	+192.0
$CaO(s)$	+91.6

(A) 3.1×10^{-18}

(B) 3.6×10^{-5}

(C) 0.11

(D) 9.4

(E) 2.8×10^{4}

23. Given the following data, calculate **ΔGº** for the reaction: $2C(s) + H_2(g) \rightarrow C_2H_2(g)$

$C_2H_2(g) + 5/2\ O_2(g) \rightarrow 2\ CO_2(g) + H_2O(l)$ $\Delta G^o = -1234$ kJ

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta G^o = -394$ kJ

$H_2(g) + ½\ O_2(g) \rightarrow H_2O(l)$ $\Delta G^o = -237$ kJ

(A) +209 kJ

(B) +366 kJ

(C) +603 kJ

(D) -603 kJ

(E) -1865 kJ

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24. Calculate the standard Gibbs free energy change, **ΔG^o**, at a temperature of **425 K**, for the reaction

$$2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$$

The following information was determined at 298 K.

	$CO(g)$	$O_2(g)$	$CO_2(g)$
ΔH_f^o / (kJ/mol)	-110.5	0	-393.5
S^o / (J/mol·K)	198	205	214
ΔG_f^o / (kJ/mol)	-137	0	-394

(A) -566.0 kJ

(B) -639.5 kJ

(C) -514 kJ

(D) -492.5 kJ

(E) +72.9 kJ

25. What is the value of the **equilibrium constant, K**, at 25.00°C, for the spontaneous overall reaction (balanced using smallest integer coefficients), constructed from the half-reactions described below?

	E^o_{red}
$Mn^{2+}(aq) + 2\ e^- \rightarrow Mn(s)$	−1.18 V
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.15 V

(A) 6×10^{18}

(B) 3×10^{22}

(C) 7×10^{34}

(D) 9×10^{44}

(E) 1×10^{50}

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26. Given the following half-reactions, identify the **best reducing agent**.

	E^o_{red}
$2\ Hg^{2+}(aq) + 2\ e^- \rightarrow Hg_2^{2+}(s)$	+0.92 V
$N_2(g) + 5\ H^+(aq) + 4\ e^- \rightarrow N_2H_5^+(aq)$	–0.23 V
$Sn^{4+}(aq) + 2\ e^- \rightarrow Sn^{2+}(aq)$	+0.13 V

(A) $Sn^{2+}(aq)$

(B) $Hg^{2+}(aq)$

(C) $N_2(g)$

(D) $Hg_2^{2+}(aq)$

(E) $N_2H_5^+(aq)$

27. Given the following standard reduction potentials, select the **correct cell diagram** for the voltaic (spontaneous) cell.

	E^o_{red}
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82 V
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80 V

(A) $Ag(s) | Ag^+(aq, 1\ M) \| Pt(s) | Co^{3+}(aq), Co^{2+}(aq, 1M)$

(B) $Pt(s) | Co^{2+}(aq), Co^{3+}(aq, 1M) \| Ag^+(aq, 1\ M) | Ag(s)$

(C) $Ag(s) | Ag^+(aq, 1\ M) \| Co^{3+}(aq), Co^{2+}(aq, 1M) | Pt(s)$

(D) $Pt(s) | Co^{2+}(aq), Co^{3+}(aq, 1M) \| 3\ Ag^+(aq, 1\ M) | 3\ Ag(s)$

(E) $Ag(s) | Ag^+(aq, 1\ M) \| Co^{2+}(aq) | Pt(s) | Co^{3+}(aq, 1M)$

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28. Given the following half reactions, calculate the **standard cell potential** for the spontaneous cell reaction.

	E^o_{red}
$MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^- \rightarrow Mn^{2+}(aq) + 4\,H_2O(l)$	+1.51 V
$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$	+0.34 V

(A) +1.85 V

(B) +1.32 V

(C) +1.17 V

(D) −1.17 V

(E) −1.85 V

Questions 30 – 36 are worth 3 marks each:

29. Given the following half-reactions, identify the **TRUE** statements regarding the operation of the electrochemical cell, and the overall spontaneous cell reaction (balanced using smallest integer coefficients).

	E^o_{red}
$Cr^{3+}(aq) + 3\,e^- \rightarrow Cr(s)$	−0.74 V
$Pb^{2+}(aq) + 2\,e^- \rightarrow Pb(s)$	−0.13 V

i) The total number of electrons transferred in this redox process is 12.

ii) Cr(s) is the anode.

iii) The mass of the Pb(s) electrode decreases during the running of the cell.

iv) $Pb^{2+}(aq)$ is a better oxidizing agent than $Cr^{3+}(aq)$.

v) As the cell operates, anions flow through the salt bridge, from the Pb half-cell to the Cr half-cell.

(A) i, ii, iv

(B) ii, iii, v

(C) ii, iv, v

(D) i, iii, v

(E) ii, iv

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30. Given the following half-reactions, identify the **FALSE** statements regarding the operation of the electrochemical cell, and the overall spontaneous cell reaction (balanced using smallest integer coefficients).

	E^{o}_{red}
$Au^{3+}(aq) + 3\,e^{-} \rightarrow Au(s)$	+1.50 V
$Cd^{2+}(aq) + 2\,e^{-} \rightarrow Cd(s)$	–0.40 V

i) $\Delta G°$ for the spontaneous cell reaction is -1.10×10^{3} kJ at 25ºC.

ii) Increasing the concentration of $Cd^{2+}(aq)$ will increase the cell voltage.

iii) As the cell operates, Cd^{2+} ions flow toward the Cd electrode.

iv) During the running of the cell, two moles of Au^{3+} ions are consumed as three moles of Cd^{2+} ions are produced.

v) Reduction takes place at the Au(s) electrode.

(A) i, ii, iii

(B) ii, iv, v

(C) ii, iii

(D) i, iv

(E) iii, v

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31. In an electrochemical cell, chlorine gas is reduced. The concentrations of Cl^- (aq) and I^- (aq) are 1.15 M and 0.65 M, respectively, and the observed cell potential (E_{cell}) is 0.807 V. Given the following standard reduction potentials,

	E^o_{red}
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.360 V
$I_2(s) + 2e^- \rightarrow 2I^-(aq)$	+0.530 V

Calculate the **partial pressure of $Cl_2(g)$** (in atm),

(A) 2.2 atm

(B) 1.3 atm

(C) 0.96 atm

(D) 0.52 atm

(E) 0.053 atm

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32. Identify the **TRUE** statement(s) among the following (central atoms are underlined):

i) An $\underline{A}X_2E_3$ molecule has a bent or angular geometry.

ii) The thiocyanate anion, $S\underline{C}N^-$, is linear and its Lewis structure contains three non-bonding electron pairs.

iii) The $\underline{N}Cl_3$ molecule is planar but the $\underline{B}Cl_3$ molecule is not.

iv) The $\underline{C}O_3^{2-}$ and $\underline{S}O_3$ species belong to the same $\underline{A}X_n$ VESPR class.

v) The $\underline{P}Cl_5$ molecule contains six 90° bond angles.

(E) i, ii, iii

(F) i, v

(G) ii, iii, iv

(H) iv

(I) iv, v

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35. If light with a wavelength of 400. nm falls on the surface of sodium metal, electrons with a kinetic energy of 1.31×10^{-19} J are ejected. The **minimum frequency** of light required to eject an electron from sodium is:

(A) 5.52×10^{14} Hz

(B) 6.63×10^{-19} Hz

(C) 3.00×10^{8} Hz

(D) 3.66×10^{-19} Hz

(E) 7.50×10^{14} Hz

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Some general data are provided on this page. Other data appear with the questions.

R = 8.314 J/K·mol = 0.08206 L·atm/K·mol

$N_A = 6.022 \times 10^{23}$ mol^{-1}

1 atm = 760 mm Hg = 101.325 kPa

0°C = 273.15 K

$1\text{cm}^3 = 1$ mL

$1\text{ J} = 1\text{ kg m}^2\text{ s}^{-2} = 1$ kPa·L

$1\text{ m} = 10^9\text{ nm} = 10^{10}$ Å

1 Hz = 1 cycle/s

$c = 3.00 \times 10^8$ m/s

$h = 6.626 \times 10^{-34}$ Js

$m_e = 9.10 \times 10^{-31}$ kg

F = 96487 C/mol

$\lambda = h / mv = h / p$

$\Delta x \Delta p \geq h / 4\pi$

$E_n = -R_H / n^2 = -2.18 \times 10^{-18}\text{J} / n^2$

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

$$E = E^\circ - \frac{RT}{nF}\ln Q = E^\circ - \frac{0.0257V}{n}\ln Q = E^\circ - \frac{0.0592V}{n}\log Q$$

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