Name:_____ **Student Number:** _____

Chemistry 1A03 **Final Exam** **February, 2010**

McMaster University VERSION 1

Instructor: P. Britz-McKibbon, G. Goward, P. Hatala, J. Landry

Duration: 3 Hours

This test contains 24 numbered pages printed on both sides. There are 35 multiple-choice questions appearing on pages numbered 3 to 21. Page 23 includes some useful data and equations. There is a periodic table on page 24. You may tear off the last page to view the periodic table and to do your rough work.

You must enter your name and student number on the question sheets, as well as on the answer sheet. Your invigilator will be checking your student card for identification.

You are responsible for ensuring that your copy of the question paper is complete. Bring any discrepancy to the attention of your invigilator.

Questions 1 to 30 are each worth 2 marks, questions 31 - 35 are each worth 3 marks; the total marks available are 75. There is no additional penalty for incorrect answers.

BE SURE TO ENTER THE CORRECT VERSION OF YOUR TEST (shown near the top of page 1), IN THE SPACE PROVIDED ON THE ANSWER SHEET.

ANSWER ALL QUESTIONS ON THE ANSWER SHEET, IN PENCIL.
Instructions for entering multiple-choice answers are given on page 2.

SELECT ONE AND ONLY ONE ANSWER FOR EACH QUESTION from the answers (A) through (E). No work written on the question sheets will be marked. The question sheets may be collected and reviewed in cases of suspected academic dishonesty.

Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, etc.) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem please ask the invigilator to deal with it for you. Do not make contact with other students directly. Try to keep your eyes on your own paper – looking around the room may be interpreted as an attempt to copy.

Only Casio FX 991 electronic calculators may be used; but they must NOT be transferred between students. Use of periodic tables or any aids, other than those provided, is not allowed.

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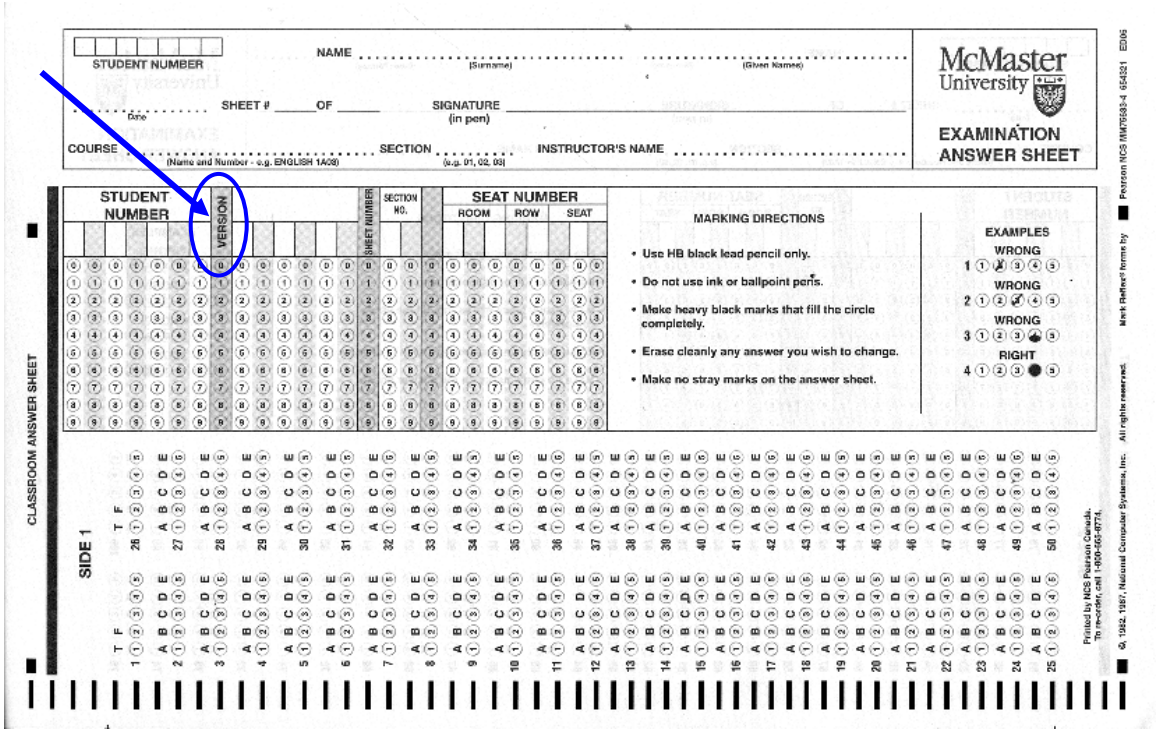
OMR EXAMINATION – STUDENT INSTRUCTIONS

NOTE: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED: YOUT EXAMINIATION RESULT DEPENDS UPON PROPER ATTENTION TO THESE INSTRUCTIONS.

The scanner, which reads the sheets, senses the bubble shaded areas by their non-reflection of light. A heavy mark must be made, completely filling the circular bubble, with an HB pencil. Marks made with a pen will NOT be sensed. Erasures must be thorough or the scanner will still sense a mark. Do NOT use correction fluid on the sheets. Do NOT put any unnecessary marks or writing on the sheet.

1. On SIDE 1 (red side) of the form, in the top box, in pen, print your student number, name, course name, and the date in the spaces provided. Then you MUST write your signature, in the space marked SIGNATURE.
2. In the second box, with a pencil, mark your student number, exam version number in the space provided and <u>fill in the corresponding bubble numbers underneath</u>.
3. Answers: mark only ONE choice from the alternatives (A,B,C,D,E) provided for each question. The question number is to the left of the bubbles. Make sure that the number of the question on the scan sheet is the same as the number on the test paper.
4. Pay particular attention to the Marking+ Directions on the form.
5. Begin answering the question using the first set of bubbles, marked “1”.



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You are writing VERSION 1 of this test. Make sure you have correctly entered your version number ("1") in the correct column on your scan sheet (see p. 2 for details).

Section #1 – These questions are worth two marks each.

___ 1. What would be the **heat capacity** of a bomb calorimeter if the combustion of hydrogen (1 mole) with excess oxygen caused the temperature to rise from 298 K to 316 K.
($\Delta H^{o}_{f}\, H_2O(l)$ = -286 kJ mol^{-1})

a. 3.45 J K^{-1}
b. 5.02 x 10^{3} J K^{-1}
c. 9.87 x 10^{2} J K^{-1}
d. 1.59 x 10^{4} J K^{-1}
e. 6.98 x 10^{1} J K^{-1}

___ 2. A system initially has an internal energy U = 520 J. It undergoes an exothermic process during which 111 J of heat is exchanged with the surroundings and 222 J of work is done on the system. What is the **final internal energy of the system?**

a. 194 J
b. 431 J
c. 852 J
d. 631 J
e. 345 J

Continued on next page…

Name:_____ **Student Number:** _____

___ 3. Determine the **false** statement below.

a. Converting elemental chlorine into chlorine atoms is endothermic
b. In a constant volume system, $\Delta U = q$
c. A beaker would represent an open system
d. Photosynthesis is an endothermic process
e. During the combustion of hydrogen at room temperature, work is done on the surroundings

___ 4. Calculate the **standard enthalpy of formation for hydrogen chloride gas** given the following data:

$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ $\Delta H^o = -175.00$ kJ
$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$ $\Delta H^o = -99.22$ kJ
$N_2(g) + 4\ H_2(g) + Cl_2(g) \rightarrow 2\ NH_4Cl(s)$ $\Delta H^o = -628.86$ kJ

a. -231.84 kJ
b. -72.50 kJ
c. -89.82 kJ
d. -439.94 kJ
e. -154.38 kJ

___ 5. Using the bond energy (BE) below to calculate the ΔH^o for the reaction

$$SO_2(g) + PCl_5(g) \rightarrow SOCl_2(g) + POCl_3(g)$$

BE (S=O) = 536 kJ·mol^{-1}
BE (P=O) = 460 kJ·mol^{-1}
BE (P–Cl) = 331 kJ·mol^{-1}
BE (S–Cl) = 250 kJ·mol^{-1}

a. + 238 kJ
b. + 389 kJ
c. - 123 kJ
d. - 348 kJ
e. - 578 kJ

Continued on next page...

___ 6. Consider the following following reaction where A and D are elements in their standard states.

$$A + 3\ B \rightarrow C + 2\ D$$

ΔH^o for the reaction would be given by

a. ΔH^o_f (C) - ΔH^o_f (A) - 3*ΔH^o_f(B)

b. ΔH^o_f (A) + ΔH^o_f (B) - ΔH^o_f (C) - ΔH^o_f(D)

c. ΔH^o_f (C) + ΔH^o_f (D) - ΔH^o_f (A) - ΔH^o_f(B)

d. ΔH^o_f (C) - 3* ΔH^o_f (B)

e. ΔH^o_f (A) + 3*ΔH^o_f (B) - ΔH^o_f (C) - 2*ΔH^o_f(D)

___ 7. In a calorimetry experiment, a respectable scientist is attempting to measure the enthalpy change for the following reaction:

$$H^+(aq) + Mg(s) \rightarrow Mg^{2+}(aq) + H_2(g)$$

$H^+(aq)$ is the limiting reagent in the experiment and when attempting to introduce the acid into the calorimeter, a portion is spilled outside the calorimeter. **The scientist should:**

a. Add approximately the amount of acid that was lost from the stock solution.

b. Continue and explain the result in their discussion as a source of human error

c. Continue with the remaining acid, estimating the acid loss and account for this in the final calculations

d. Obtain a new, accurate amount of acid.

e. Remove some Mg to account for the acid loss.

Continued on next page…

___ 8. Based on the following information:

N_2 (g) + O_2 (g) $\rightleftharpoons$ 2NO (g) $K_1 = 4.3 \times 10^{-25}$

NO_2 (g) $\rightleftharpoons$ NO (g) + ½ O_2(g) $K_2 = 1.3 \times 10^{-5}$

Calculate K_c for:

N_2 (g) + 2O_2 (g) $\rightleftharpoons$ 2NO_2 (g) K_c = ?

a. 3.1×10^{-15}
b. 2.5×10^{-15}
c. 7.1×10^{-25}
d. 5.5×10^{-30}
e. 4.8×10^{-13}

___ 9. The partition coefficient K_{ow} describes the distribution of a persistent organic pollutant (POP) as shown by:

POP(aq) $\rightleftharpoons$ POP(octanol)

Select the **TRUE** statements about K_{ow}. It is:

i. a measure of the bond energy of the POP.

ii. related to the dipole moment of the POP.

iii. used to assess tendency of the POP to bio-accumulate in fatty tissue.

iv. determined by mixing the POP with water and soap.

a. ii, iv
b. i, iii
c. i, ii
d. ii, iii
e. i, iv

Continued on next page…

___ 10. The following reaction takes place in a sealed steel container at 25.0°C.

$$C(\text{graphite}) + 2H_2(g) \rightleftharpoons CH_4(g) \qquad K_p = 45.1$$

The system is allowed to reach equilibrium and then 5 atm of argon gas is added. **The effect will be:**

a. Since this is a constant volume system, the argon was will shift the equilibrium to the right

b. Since this is a constant volume system, the argon gas will not affect the equilibrium

c. Since this is a constant pressure system, the argon gas will shift the equilibrium to the right

d. The argon gas will react with the hydrogen gas, lowering it's partial pressure and shifting the reaction to the left

e. Since this is a constant pressure system, the argon gas will not affect the equilibrium

___ 11. **Which one of the following interactions** account for the efficacy of chemical sunscreens in preventing radiation damage to cell tissue?

a. The quantized transitions in heavy metals like lead, upon absorbing incident light

b. The ability of aromatic molecules to absorb UVA/UVB light.

c. The absorption of electrons by low work function elements

d. The tendency of lipophilic drugs to bioaccumulate.

e. The interaction of sound waves with water.

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___ 12. 523.0 mL of acetylene (C_2H_2) was collected over water at 23.0°C and a total barometric pressure of 0.9711 atm. If the vapour pressure of water at 23.0°C is 0.0276 atm, **how many grams of acetylene were collected?**

a. 0.211 g
b. 0.318 g
c. 0.913 g
d. 0.528 g
e. 0.861 g

___ 13. **Calculate the wavelength** of a tennis ball travelling at 52 m/s if the ball weighs 70. g.

a. 1.8×10^{-34} m
b. 3.1×10^{-34} m
c. 4.7×10^{-20} m
d. 9.1×10^{-25} m
e. 3.1×10^{-25} m

___ 14. Which of the following statements is **false**?

a. Bohr's model of the atom put electrons in a random cloud around the atom
b. De Broglie combined Einstein's energy equation with Planck's energy equation to derive an equation that determines the wavelength of particles with mass
c. If there are 3 electrons in a p-subshell, the ground state configuration will have them all with the same magnetic spin
d. For l=0, there is only one subshell
e. An electron in hydrogen requires $-R_H/n^2$ joules of energy to be ionized

Continued on next page...

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___ 15. Which of the following **differences in ionization energy** would you expect to be the **largest for phosphorous?**

a. I.E. 1 → I.E. 2
b. I.E. 3 → I.E. 4
c. I.E. 2 → I.E. 3
d. I.E. 5 → I.E. 6
e. I.E. 0 → I.E. 1

___ 16. Which of the following statements below is false about the series of ions listed:

Cl^- Na^+ O^{2-} Rb^+ Se^{2-}

a. Rb^+ has a larger ionic radius than Na^+
b. O^{2-} and Na^+ are isoelectronic
c. Se^{2-} has the largest ionic radius
d. Na^+ has the smallest ionic radius
e. Rb^+ and Cl^- are isoelectronic

___ 17. Based on a formal-charge minimized Lewis structure for TeO_4^{2-} **the average Te-O bond order (BO) and O formal charge (FC) would be:**

	B.O.	F.C.
a.	1	1
b.	1.5	-0.5
c.	1	-1.5
d.	0.7	-0.5
e.	2.5	-2

Continued on next page...

___ 18. Which of the following salts will form a **weakly acidic solution** upon dissolution:

i. CaI_2
ii. NH_4Cl
iii. $NaOOCH_3$
iv. KNO_3
v. HF

a. i
b. iv
c. ii, v
d. ii, iii
e. i, iv

___ 19. Which of the following statements is **correct?**

a. H_2SeO_4 > H_2SeO_3 - the stronger acid is listed first
b. HCl > HBr - the stronger acid is listed first
c. PH_3 > H_2S - the stronger acid is listed first
d. CH_3COOH > CCl_3COOH - the stronger acid is listed first
e. NI_3 > NH_3 - the stronger base is listed first

Continued on next page...

___ 20. Which of the following statements are **TRUE**?

i. For binary acids, the larger the electronegativity difference, the easier it is to remove a proton, and therefore the stronger the acid.

ii. The position of a halogen atom relative to the carboxyl group influences the strength of an oxyacid because it weakens the O-H bond by with drawing electron density from oxygen

iii. When comparing two different oxyacids, the one with the greater number of protons will be the stronger acid, because there are more protons to donate

iv. The presence of a halogen on an amine (for example, NH_2Cl) weakens it as a base because it makes the nitrogen more positive and therefore less likely to accept a proton

v. The more charge-minimized resonance structures that can be drawn for the conjugate base of an oxyacid the stronger the acid

a. iii, v
b. ii, iv
c. i, iv, v
d. i, iii, iv
e. ii, iv, v

Continued on next page...

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___ 21. Select the correct **whole-number coefficient terms for H_2O_2, Mn^{2+} and H_2O** after balancing the following redox equation under **acidic conditions**:

$$MnO_4^-(aq) + H_2O_2(aq) \rightarrow Mn^{2+}(aq) + O_2(g)$$

a. 3, 1, 4
b. 1, 3, 5
c. 2, 4, 6
d. 4, 6, 1
e. 5, 2, 8

___ 22. Which of the following statements are **FALSE**?

a. The production of iron from iron ore requires coke, C (s) as the oxidizing agent
b. Flue gas desulfurization technology uses a slaked lime slurry, $Ca(OH)_2$ to reduce the impact of gas emissions associated with acid rain
c. Hydroxylapatite from charred bone can be used as a filter to selectively absorb chloride from contaminated water
d. HF is a stronger acid than HCl due to its weaker bond energy
e. Cold packs function based on the dissolution of ammonium nitrate which is highly endothermic

a. i, v
b. ii, iii, v
c. iii, iv
d. i, iii, iv
e. ii, iii

Continued on next page...

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___ 23. Determine the **K_{sp} of mercury (II) bromide** if the equilibrium concentration of bromide in solution is measured to be 5.00×10^{-7} M at 25°C:

a. 4.37×10^{-16}
b. 8.72×10^{-25}
c. 1.67×10^{2}
d. 2.96×10^{-44}
e. 6.25×10^{-20}

___ 24. Predict whether the following unbalanced chemical reactions will form an **insoluble precipitate**:

i. $BaCl_2$ (aq) + $NaHPO_4$ (aq) + K_2S (aq) →
ii. Zn (s) + H^+ (aq) →
iii. $AlCl_3$ (aq) + NaOH (aq) →
iv. $AgNO_3$ + NaCl (aq) →
v. NH_4Cl (aq) + LiBr (aq) →

a. ii, iii, v
b. iii, v
c. i, iii, iv
d. ii, v
e. i, ii

Continued on next page...

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___ 25. The voltaic cell with the net reaction represented by the following equation has:

$$E°_{cell} = -0.760 \text{ V at } 25 °C.$$

$$\mathbf{H_2(g) + Zn^{2+} \rightarrow Zn(s) + 2H^+(aq)}$$

Calculate $\Delta G°$ at 25 °C. What is the direction of spontaneous reaction in a cell at 25 °C in which all species are in their standard states?

a. 283 kJ, spontaneous in the reverse direction
b. 147 kJ, spontaneous in the forward direction
c. 147 kJ, spontaneous in the reverse direction
d. -84.5 kJ, spontaneous in the forward direction
e. -84.5 kJ, spontaneous in the reverse direction

___ 26. For each of the pairs listed, **which is ordered from highest entropy to lowest entropy**. Assume all substances are at 25°C, and 1atm.

a. 1 mol of $SnCl_4(g)$, 1 mol of $SnCl_4(l)$
b. 1 mol of C(s) diamond, 1 mol of C(s) graphite
c. 1 mol of $H_2O(l)$, 1 mol of $NH_3(l)$
d. 1 mol of $O_2(g)$, 1 mol of $O_3(g)$
e. 1 mol of ethene (g) , 1 mol of ethane (g)

Continued on next page...

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___ 27. Oxygen was first made by Joseph Priestley (1733-1804) by heating HgO(s). Use the thermodynamic data below, that apply at 25 °C, to **estimate the temperature** at which HgO(s) in a sealed vessel decomposes sufficiently to be in equilibrium with 1 atm pressure of $O_2(g)$.

(Hint: Finding the temperature at which $\Delta G_r° = 0$)

$$2HgO(s) \rightarrow 2Hg(l) + O_2(g)$$

$S^0(Hg,l) = 76.02\ JK^{-1}mol^{-1}$
$\Delta H_f^0(HgO,s) = -90.83\ kJmol^{-1}$
$S^0(O_2,g) = 205.138\ JK^{-1}mol^{-1}$
$S^0(HgO,s) = 70.29\ JK^{-1}mol^{-1}$

a. T = 735.8 K
b. T = 911.5 K
c. T = 553.4 K
d. T = 838.7 K
e. T = 445.2 K

___ 28. Which of the following correctly represent the thermodynamics of the given reactions:

Reaction	**ΔH^o kJ**	**ΔS^o J/K**	**Reaction Type**
i. $CH_4(g) + 2O_2(g) \rightarrow 2H_2O(l) + CO_2(g)$	-890.6	-242.8	spontaneous at low T, NOT spontaneous at high T
ii. $2Fe_2O_3(s) + 3C(graphite) \rightarrow 4Fe(s) + 3CO_2(g)$	+467.9	+560.7	NOT spontaneous at low T, spontaneous at high T
iii. $C(graphite) + O_2(g) \rightarrow CO_2(g)$	-393.5	+3.1	spontaneous at all T
iv. $N_2(g) + 3F_2(g) \rightarrow 2NF_3(g)$	-264.2	-277.8	non spontaneous at all T

a. i, ii, iii
b. ii, iv
c. iii, iv
d. ii, iii
e. i, iv

Continued on next page...

___ 29. A crucial reaction for the production of synthetic fuels is the conversion of coal to H_2 with steam. **Calculate the value of *K*** for the reaction at 25 °C.

$$\Delta G_f^0(H_2O,g) = -228.572\ kJmol^{-1} \quad \Delta G_f^0(CO,g) = -137.168\ kJmol^{-1}$$

$$C(graphite) + H_2O(g) \rightarrow H_2(g) + CO(g)$$

a. 9.50×10^{-17}
b. 4.43×10^{-3}
c. 6.55×10^{18}
d. 1.10×10^{-8}
e. 3.87×10^{-12}

___ 30. Choose the **false** statement from the following:

a. For a spontaneous reaction, the sum of the entropy change of the system and the surroundings must be greater than zero.
b. The spontaneous reaction of sodium azide upon detonation of an airbag is driven by the formation of the stable nitrogen triple bond.
c. The spontaneous reaction in a galvanic cell provides a means of capturing electrical energy with high efficiency.
d. The usefulness of the Gibbs Free Energy is that the sponaneity of a reaction may be determined through consideration of the system alone.
e. Phase transitions occur spontaneously because ΔG at the transition is less than zero, and the equilibrium constant is greater than 1.

Continued on next page...

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Section #2 – These questions are worth three marks each.

___ 31. Two beakers of ethylene glycol are mixed in a closed system. Beaker A is twice the volume and at 4 times the temperature of Beaker B, which is at 10^{o}C. What is the **final temperature** of the combination.

a. 30^{o}C
b. 80^{o}C
c. 15^{o}C
d. 33.33^{o}C
e. 20^{o}C

Continued on next page...

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____ 32. Consider the following chemical equilibrium:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

If absorbance = 540*[$FeSCN^{2+}$] (the only species that absorbs visible light), **determine the equilibrium constant** when equal volumes of 2.5 x 10^{-3} M solutions of $Fe(NO_3)_3$ and KSCN are mixed together and produce and absorbance of 0.34 at 447 nm.

a. 1600
b. 40
c. 560
d. 1.5 x 10^{-3}
e. 3400

Continued on next page...

____ 33. Calculate the **pH** of a saturated solution containing the **sparingly soluble solid**, $Ca(OH)_2$ given that its K_{sp} = 5.02 x 10^{-6} at 25°C:

a. 4.652
b. 7.254
c. 12.334
d. 2.527
e. 9.843

Continued on next page...

____ 34. One half-cell in a voltaic cell at 25 °C is constructed from a silver wire dipped into a $AgNO_3$ solution of unknown concentration. The other half-cell consists of a zinc electrode in a 1.0 M $Zn(NO_3)_2$ solution. The cell emf is measured to be 1.48 V. **What is the concentration of Ag^+(aq) ions?** The reduction potentials involved are:

$Ag^+(aq) \rightarrow Ag(s)$ $E^o = 0.7994V$
$Zn^{2+}(aq) \rightarrow Zn(s)$ $E^o = -0.763V$

a. 0.84 M
b. 0.018 M
c. 0.22 M
d. 0.35 M
e. 0.041 M

Continued on next page...

____ 35. The thermodynamic data relevant to the vapour pressure of ethanol (at 25°C) is $\Delta H_{vap}°$ is 39.33 kJ mol^{-1}, and $\Delta G_{vap}°$ is 6.29 kJ mol^{1} **Estimate the boiling point of ethanol** at 1.0 atm pressure (the temperature at which the equilibrium vapour pressure is equal to 1.0 atm).

a. 76
b. 82
c. 90
d. 94
e. 73

Continued on next page...

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ROUGH WORK

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

A periodic table is provided on the next page.

STP = 273.15 K, 1 atm F = 96485 C/mol

R = 8.3145 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 J = 1 kg m^2 s^{-2} = 1 kPa·L = 1 Pa·m^3 1 m = 109 nm = 1010 Å

1 cm^3 = 1 mL 1 g = 103 mg = 10^{-3} kg

1 Hz = 1 cycle/s $c = 2.9979 \times 10^8$ m/s

$h = 6.6256 \times 10^{-34}$ J·s $m_e = 9.10 \times 10^{-31}$ kg

λ = h / mu = h / p

En = $-R_H / n^2 = -2.179 \times 10^{-18} J / n^2$ (R_H is the energy form of the Rydberg constant for H)

$K_w = 1.0 \times 10^{-1}4$ (25 °C) C_{water} = 4.184 J/g·K

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

$$E_{cell} = E^o{}_{cell} - \frac{RT}{nF}\ln Q = E^o{}_{cell} - \frac{0.0592}{n}\log_{10} Q$$

TABLE 5.1 Solubility Guidelines for Common Ionic Solids

Follow the lower-numbered guideline when two guidelines are in conflict. This leads to the correct prediction in most cases.

1. Salts of group 1 cations (with some exceptions for Li^+) and the NH_4^+ cation are soluble.
2. Nitrates, acetates, and perchlorates are soluble.
3. Salts of silver, lead, and mercury(I) are insoluble.
4. Chlorides, bromides, and iodides are soluble.
5. Carbonates, phosphates, sulfides, oxides, and hydroxides are insoluble (sulfides of group 2 cations and hydroxides of Ca^{2+}, Sr^{2+}, and Ba^{2+} are slightly soluble).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

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PERIODIC TABLE OF THE ELEMENTS

ALDRICH®

I 1	II 2	3	4	5	6	7	8	9	10	11	12	III 13	IV 14	V 15	VI 16	VII 17	VIII 18
1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** [98]	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 105.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** [209]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223]	88 **Ra** 226.03	89 ****Ac** 227.03	104 **Unq** [261]	105 **Unp** [262]	106 **Unh** [263]												

Transition Metals (groups 3–12)

Atomic weights are based on $^{12}C = 12$ and conform to the 1987 IUPAC report values rounded to 5 significant digits.
Numbers in [ ] indicate the most stable isotope.

* Lanthanides	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
** Actinides	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** [244]	95 **Am** [243]	96 **Cm** [247]	97 **Bk** [247]	98 **Cf** [251]	99 **Es** [252]	100 **Fm** [257]	101 **Md** [258]	102 **No** [259]	103 **Lr** [262]