Name: _____ **Student number:** _____

Chemistry 1A03/1E03 **December, 2005**

VERSION 1

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Duration: 3 hours

MCMASTER UNIVERSITY FINAL EXAMINATION

This exam contains 28 numbered pages. There are **35** multiple-choice questions appearing on pages numbered 3 to 23. Pages 24-26 are extra space for rough work. Page 27 includes some useful data and equations, and there is a periodic table on page 28. You may tear off the last pages to view the periodic table and the data provided.

These question sheets must be returned with your answer sheet. However, no work written on the question sheets will be marked. **You must enter your full name and student number on this question sheet, 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 25 are each worth 2 marks, questions 26 – 35 are each worth 3 marks; the total marks available are 80. 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 CORRECT COLUMN 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).**

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.

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. 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.

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Name: _____ **Student number:** _____

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.

Questions 1 – 25 are worth 2 marks each.

1. A sample of hydrogen atoms have their electrons excited to various energy levels; this is followed by emission of light. **Which one of the following transitions** would produce the photons with the shortest wavelength?

(A) $n = 2 \rightarrow n = 1$

(B) $n = 3 \rightarrow n = 2$

(C) $n = 7 \rightarrow n = 6$

(D) $n = 5 \rightarrow n = 2$

(E) $n = 4 \rightarrow n = 1$

2. The O–H bond energy in water is approximately 467 kJ mol^{-1}. The photon with just enough energy to break one O–H bond has a **wavelength (in nm)** of

(A) 256 nm

(B) 23.7 nm

(C) 4130 nm

(D) 213 nm

(E) 467 nm

Continued on next page

4. Select the statement that is **FALSE** regarding the perchlorate anion, ClO_4^-, with a charge minimized Lewis structure.

(A) The formal charge of Cl is 0.

(B) The oxidation state of Cl is +7.

(C) The average Cl–O bond order is 1½.

(D) The shape of the anion is tetrahedral.

(E) The anion has 18 nonbonding valence electrons.

5. Select the **ONE TRUE** statement concerning the following molecules:

CH_4 PH_3 SeH_2

(A) One of these molecules is an exception to the octet rule.

(B) There are lone pairs of electrons in all of these molecules.

(C) All the H–A–H angles are equal in these three molecules (A is the central atom).

(D) H has a negative oxidation state in at least one of these molecules.

(E) Considering bonding and nonbonding electron pairs, all these molecules have the same VSEPR electron-group arrangement.

 Continued on next page

6. Which **ONE** of the following pairs of reagents produces **no visible change** when they are mixed together?

(A) $Cl_2(g) + KBr(aq)$

(B) $KCl(aq) + AgClO_4(aq)$

(C) $Zn(s) + HI(aq)$

(D) $Na_2CO_3(s) + HCl(aq)$

(E) $Cu(s) + HCl(aq)$

7. Given $\Delta H_f°(NF_3, g) = -132$ kJ mol^{-1} and the following bond energy (BE) data: $BE(N_2) = 946$ kJ mol^{-1}, $BE(F_2) = 159$ kJ mol^{-1}, which of the following statements is(are) **FALSE**?

(i) The average N-F bond energy in NF_3 is 281 kJ mol^{-1}.

(ii) The average N-F bond energy in NF_3 is 193 kJ mol^{-1}.

(iii) $\Delta H_f°(F(g)) = +159$ kJ mol^{-1}

(A) i

(B) ii

(C) iii

(D) i, ii

(E) ii, iii

Continued on next page

8. Acetylene gas (C_2H_2 (g)) has a standard enthalpy of formation of +226 kJ mol^{-1}. Under pressure, acetylene can react with itself to form benzene (C_6H_6 (l)), whose standard enthalpy of formation is +49 kJ mol^{-1}. The **enthalpy of reaction** of forming 1.0 mole of benzene from acetylene is:

(A) –177 kJ
(B) –275 kJ
(C) –629 kJ
(D) –727 kJ
(E) –210 kJ

9. Which of the following statements is(are) **FALSE**?

(i) The sign of work (w) done by a system is negative.
(ii) If ΔE is zero and w is positive, then heat (q) must be positive.
(iii) Electrical work can be calculated from charge transferred × voltage.
(iv) An ideal ice calorimeter does not exchange heat with its surroundings.
(v) When a gas expands at constant pressure, w for the gas is positive.

(A) i, iv
(B) ii, v
(C) iii, iv
(D) i, ii, v
(E) ii, iii

 Continued on next page

10. The standard enthalpies of combustion of acetylene (C_2H_2 (g)), hydrogen (H_2(g)) and ethane (C_2H_6 (g)) are –1305 kJ mol^{-1}, –285.8 kJ mol^{-1} and –1541 kJ mol^{-1}, respectively, at 298.15 K. What is the **standard enthalpy of the reaction (kJ)** of acetylene plus hydrogen to form one mole of ethane?

(A) –335.6 kJ
(B) –49.8 kJ
(C) –3417.6 kJ
(D) +49.8 kJ
(E) –2274.4 kJ

11. In a thermochemistry experiment, a reaction between 4 M hydrochloric acid and 4 M sodium hydroxide is carried out in an ice calorimeter. Select the **FALSE** statement(s).
    (i) The reaction enthalpy determined in the experiment will be the same if 4 M nitric acid is used instead of 4 M hydrochloric acid.
    (ii) The reaction leads to an increase in volume of the water plus ice mixture inside the calorimeter.
    (iii) The ice calorimeter works at 0° C and at constant pressure.
    (iv) Measured volume change = (volume of ice melted) – (volume of water produced from melting ice).

(A) i
(B) ii
(C) iii
(D) i, ii
(E) iv

 Continued on next page

12. "Handwarmers" for use in cold weather consist of 4.00 g of finely-divided iron, which oxidizes to Fe_2O_3 when opened to air. Assume that the total heat capacity of your hand and the handwarmer is 836.8 J K^{-1}. The standard heat of formation of Fe_2O_3 is –822.2 kJ mol^{-1}. If the heat from a handwarmer was released to your hand all at once, the **temperature change in your hand would be**:

(A) 17.6 K
(B) 70.4 K
(C) 35.2 K
(D) 3.52 K
(E) 7.04 K

13. For which of the following reactions would you **predict $\Delta H_{rxn}° < 0$ and $\Delta S_{rxn}° > 0$** ?

(i) $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$
(ii) $Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$
(iii) $O_3(g) \rightarrow O_2(g) + O(g)$
(iv) $5\ C(s) + 4\ KNO_3(s) \rightarrow 5\ CO_2(g) + 2\ N_2(g) + 2\ K_2O(s)$

(A) i
(B) ii
(C) iii
(D) iv
(E) iii, iv

Continued on next page

14. Consider the reaction $H_2(g) + S(s) \rightarrow H_2S(g)$ for which $\Delta H° = -20$ kJ and $\Delta S° = +43$ J K^{-1} at 298.15 K. Choose the **TRUE** statement.

(A) The reaction is not spontaneous at 298.15 K.

(B) The reaction is not spontaneous at any temperature.

(C) The reaction is spontaneous only above a temperature of 465 K.

(D) The reaction is driven by enthalpy only.

(E) The reaction is spontaneous at all temperatures.

15. Select the **FALSE** statement from the following:

(A) The entropy of a system is a measure of its disorder.

(B) The standard entropy change for a chemical reaction can be calculated from the absolute entropies of reactants and products.

(C) For a system at equilibrium, $\Delta H_{sys} = -T\Delta S_{sys}$.

(D) For a spontaneous chemical reaction at 298.15 K and 1 atm, $\Delta G° < 0$.

(E) $\Delta S° < 0$ for the reaction $H_2(g) + O_2(g) \rightarrow HOOH(g)$.

16. Arrange the following substances in order of **increasing molar entropy** at 25°C:

$H_2O(l)$, $Na(s)$, $Ne(g)$, and $SO_2(g)$

(A) $H_2O(l) < SO_2(g) < Na(s) < Ne(g)$

(B) $Na(s) < H_2O(l) < Ne(g) < SO_2(g)$

(C) $Na(s) < H_2O(l) < SO_2(g) < Ne(g)$

(D) $Ne(g) < Na(s) < H_2O(l) < SO_2(g)$

(E) $Ne(g) < Na(s) < SO_2(g) < H_2O(l)$

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17. The melting point of H_2O is 0.00°C. The enthalpy of fusion (melting) for H_2O is 6.01 kJ mol^{-1}. What is the **entropy of fusion (J mol^{-1} K^{-1}) for H_2O**?

(A) +22.0 J mol^{-1} K^{-1}

(B) –22.0 J mol^{-1} K^{-1}

(C) +1.64 J mol^{-1} K^{-1}

(D) +45.5 J mol^{-1} K^{-1}

(E) –45.5 J mol^{-1} K^{-1}

18. Which of the following statements is(are) **FALSE**?

(i) All spontaneous processes increase the total entropy of the universe.

(ii) $\Delta G_{sys} < 0$ for all spontaneous processes.

(iii) The normal boiling point of a liquid is given by $\Delta H_{vaporization} / \Delta S_{vaporization}$.

(iv) At a given temperature, a reaction proceeds spontaneously in the forward direction if its reaction quotient is larger than its equilibrium constant.

(A) i

(B) i, ii

(C) ii, iii

(D) iii, iv

(E) iv

Continued on next page

21. Given the following standard reduction potentials, identify the **best reducing agent**.

	E^{o}_{red}
$2\ Hg^{2+}(aq) + 2\ e^{-} \rightarrow Hg_2^{2+}(aq)$	+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) $N_2H_5^{+}(aq)$

Continued on next page

22. The interior and exterior of a nerve cell behave as a concentration cell. If the concentration of K^+ outside the cell is 0.030 M and the concentration inside is 0.30 M, what is the potential difference across the cell membrane, in volts V? Assume normal body temperature, T = 37 °C and a one-electron transfer (n = 1).

(A) 0.198

(B) 0.0862

(C) 0.0615

(D) 0.0592

(E) 0.0267

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Questions 26 – 35 are worth 3 marks each.

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

(i) An Al^{3+} cation in its ground electronic state has no unpaired electrons.

(ii) In the He^{+} cation, the 3s and 3p orbitals have the same energy.

(iii) In the H atom, the photon from the transition from n=2 to n=1 is outside the visible range of the spectrum (400-700 nm).

(iv) B has a larger first ionization energy than Al.

(A) None is false

(B) i

(C) ii

(D) iii

(E) iv

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27. Which of the following statements is(are) **TRUE**?

(i) $TeCl_2$ is a V-shaped (or "bent") molecule.

(ii) All of the atoms of $TeCl_3^+$ are in the same plane.

(iii) $TeCl_4$ has one nonbonding pair of electrons on tellurium.

(A) i

(B) ii

(C) iii

(D) i, ii

(E) i, iii

Continued on next page

28. A copper penny weighing 1.868 g is completely dissolved in an excess of hydrochloric acid and $KMnO_4(aq)$, according to the reaction *(note that the reaction is unbalanced)*:

$$Cu(s) + KMnO_4(aq) + HCl(aq) \rightarrow CuCl_2(aq) + MnCl_2(aq) + H_2O(l) + KCl(aq)$$

The resultant solution is diluted to a final volume of 60.00 mL with water. What is the **molarity (in units of mol L^{-1}) of manganese(II) chloride** in the final solution?

(A) 0.3919 mol L^{-1}

(B) 0.01176 mol L^{-1}

(C) 0.1960 mol L^{-1}

(D) 0.4899 mol L^{-1}

(E) 0.2746 mol L^{-1}

Continued on next page

29. Consider the reaction $Si(s) + 2\ H_2(g) \rightarrow SiH_4(g)$. Use the data below to identify the **TRUE** statement(s).

DATA:

At 25 °C, $K = 1.06 \times 10^{-10}$ for the formation reaction of $SiH_4(g)$.

$\Delta H_f°(SiH_4, g) = 34.3\ kJ\ mol^{-1}$

$S°(SiH_4, g) = 204.62\ J\ K^{-1}\ mol^{-1}$

$S°(H_2, g) = 130.68\ J\ K^{-1}\ mol^{-1}$

$S°(Si, s) = 18.83\ J\ K^{-1}\ mol^{-1}$

(i) $\Delta S° > 0$ for the forward reaction.

(ii) The reverse reaction is spontaneous at all temperatures.

(iii) If $P(H_2) = 100$ atm at equilibrium at 25 °C, then $P(SiH_4) = 1.06 \times 10^{-6}$ atm.

(A) i

(B) ii

(C) iii

(D) ii, iii

(E) i, ii, iii

Continued on next page

30. Consider the following two reactions, with thermodynamic data at 298.15 K:

(1) $Pb(s) + CO(g) \rightarrow PbO(s) + C(graphite)$ $\Delta H° = -107$ kJ mol^{-1} $\Delta G° = -51$ kJ mol^{-1}

(2) $2\ C(graphite) + O_2(g) \rightarrow 2\ CO(g)$ $\Delta H° = -221$ kJ mol^{-1} $\Delta G° = -274$ kJ mol^{-1}

Which of the following statements is(are) **FALSE**? (Assume $\Delta H°$ and $\Delta S°$ are independent of temperature.)

(i) $\Delta G_f°[PbO(s)] = +188$ kJ mol^{-1} .

(ii) Both reactions are spontaneous under standard conditions at room temperature.

(iii) $\Delta S°$ for reaction 2 is -178 J K^{-1} mol^{-1} at 298.15 K.

(iv) Reaction 2 is spontaneous at 500 °C when the partial pressures of O_2 and CO are 1 atm each.

(A) i

(B) i, ii

(C) iii

(D) iv

(E) i, iii

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31. Find the **FALSE** statements about the voltaic cell based on the two reduction half-reactions below. The initial ion concentrations are $[Al^{3+}] = 0.01$ M, $[Mn^{2+}] = 0.1$ M.

$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$ $\quad E^o_{red} = -1.66$ V

$Mn^{2+}(aq) + 2e^- \rightarrow Mn(s)$ $\quad E^o_{red} = -1.18$ V

(i) Al(s) is a stronger reducing agent than Mn(s).

(ii) The cell diagram is $Al(s) \mid Al^{3+}(aq) \parallel Mn^{2+}(aq) \mid Mn(s)$.

(iii) For the balanced cell reaction the reaction quotient $Q = [Al^{3+}] / [Mn^{2+}]$.

(iv) For the initial reaction quotient Q, $\log_{10}Q = -1$.

(v) When the cell is put into operation, the initial cell potential is +0.48V.

(A) i, ii, iv

(B) ii, iii

(C) ii, v

(D) iii, v

(E) i, iv

 Continued on next page

32. An electrochemical cell is based on the spontaneous redox reaction associated with the standard reduction potentials given below. If the initial concentrations of $Cl^-(aq)$ and $I^-(aq)$ are 1.15 M and 0.65 M, respectively, and the initial cell potential (E_{cell}) is +0.807 V, calculate the initial **partial pressure of $Cl_2(g)$** (in atm) in the cell.

	E^o_{red}
$Cl_2(g) + 2\ e^- \rightarrow 2\ Cl^-(aq)$	+1.36 V
$I_2(s) + 2\ e^- \rightarrow 2\ I^-(aq)$	+0.53 V

(A) 1.3 atm

(B) 1.9 atm

(C) 0.30 atm

(D) 0.52 atm

(E) 1.4 atm

Continued on next page

33. Find the **FALSE** statement(s) about the following electrochemical cell:

$$Cu(s) \mid Cu^{2+}(aq) \parallel MnO_4^-(aq), Mn^{2+}(aq), H^+(aq) \mid Pt(s).$$

(i) Decreasing the concentration of $Cu^{2+}(aq)$ in the cell will increase the cell voltage.

(ii) Anions in the salt bridge flow towards the anode.

(iii) $H_2(g)$ is produced at the Pt(s) electrode.

(iv) Electrons flow from the Cu electrode towards the Pt electrode.

(v) Pt(s) serves as an inert (inactive) anode.

(A) i, ii

(B) iii, v

(C) iii

(D) i, iii, iv

(E) i, v

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Some general data are provided on this page and the next page.
A periodic table is provided on page 28.

Other data appear with the questions.

STP = 273.15 K, 1 atm

F = 96485 C/mol

$R = 8.3145\ J\ K^{-1}\ mol^{-1} = 0.08206\ L\ atm\ K^{-1}\ mol^{-1}$

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

1 atm = 760 mm Hg = 101.325 kPa

0°C = 273.15 K

$1\ J = 1\ kg\ m^2\ s^{-2} = 1\ kPa\ L = 1\ Pa\ m^3$

$1\ m = 10^9\ nm = 10^{10}$ Å

$1\ cm^3 = 1\ mL$

$1\ g = 10^3\ mg$

1 Hz = 1 cycle/s

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

$h = 6.6256 \times 10^{-34}$ Js

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

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

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

$E_n = -R_H / n^2 = -2.178 \times 10^{-18} J / n^2$

Note R_H is the energy form of the Rydberg constant for hydrogen

$w = -p\Delta V$

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

$E = E^o - (RT / nF) \ln Q = E^o - (0.0257 / n) \ln Q = E^o - (0.0592 / n) \log Q$

Specific heat of water = 4.184 J / g·°C

density(H_2O, l) = 1.00g/mL

Soluble Ionic Compounds

1. All common compounds of Group 1A(1) ions (Li^+, Na^+, K^+, *etc*.) and ammonium ion (NH_4^+) are soluble.
2. All common nitrates (NO_3^-), acetates (CH_3COO^- or $C_2H_3O_2^-$), and most perchlorates (ClO_4^-) are soluble.
3. All common chlorides (Cl^-), bromides (Br^-), and iodides (I^-) are soluble, *except* those of Ag^+, Pb^{2+}, Cu^+, and Hg_2^{2+}.
4. All common sulfates (SO_4^{2-}) are soluble, *except* those of Ca^{2+}, Sr^{2+}, Ba^{2+}, and Pb^{2+}.

Insoluble Ionic Compounds

1. All common metal hydroxides (OH^-) are insoluble, *except* those of Group 1A(1) and the larger members of Group 2A(2) (beginning with Ca^{2+}).
2. All common carbonates (CO_3^{2-}) and phosphates (PO_4^{3-}) are insoluble, *except* those of Group 1A(1) and NH_4^+.
3. All common sulfides (S^{2-}) are insoluble *except* those of Group 1A(1), Group 2A(2), and NH_4^+.

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Name: ____________________ **Student number:** ______________

Periodic Table of the Elements

	1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	8B (9)	8B (10)	1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1	1 **H** 1.008																	2 **He** 4.003
2	3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 (269)	111 (272)	112 (277)		114 (285)				

As of early 2002, elements 110–112 and 114 have not been named. Recently, element 116 was shown conclusively to exist.

6	Lanthanides	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
7	Actinides	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (242)	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** (260)

END OF EXAM