NAME ______________________________

GROUND RULES: This is a closed-book/closed-note exam, except that you are permitted one sheet of notes. Do your work on the paper provided. Please be sure that your name is written on each page you submit. Also, please be sure that the problem number and your answer are clearly indicated. The total score possible is 20 points, and the time allowed is 50 minutes. Use the time wisely. Good luck!

REMINDER: Read the questions **carefully**, and be certain you are responding appropriately.

HINTS:
(1) If you seem to be missing an important piece of information, assume a reasonable value, state your assumption, and proceed.
(2) Partial credit is granted, but only if your work can be understood (and your thinking is reasonable).
(3) See below for potentially relevant information.

#1 (3 max.) ______ #2 (6 max.) ______ #3 (6 max.) ______ #4 (5 max.) ______

TOTAL SCORE (20 max.) [ ] Results: UG N = 37, mean = 13.5; G N = 6, mean = 15.4

DATA AND RELATIONSHIPS

Atomic masses (g/mol):	H - 1, C - 12, N - 14, O - 16	
Composition, dry atmos.:	N_2 - 79%, O_2 - 21%	
Ideal gas law:	$pV = nRT$	
Gas constant:	$R = 82.05 \times 10^{-6}$ atm mol^{-1} m^3 K^{-1}	
Conversion factors:	pressure: 1 atm = 1.01325×10^5 Pa	
	volume: 1 m^3 = 1000 L	volume: 1 L = 1000 cm^3
	temperature: T (K) = T (°C) + 273	
Definitions:	$pH = -\log_{10}([H^+])$	$pK_A = -\log_{10}(K_A)$
Acid-dissociation:	$HA \Leftrightarrow H^+ + A^-$	$K_A = [H^+][A^-]/[HA]$
Dissociation of water:	$H_2O \Leftrightarrow H^+ + OH^-$	$K_w = [H^+][OH^-] = 10^{-14}$ M^2
Standard oxidation states of elements in compounds:		$X_O = -2$; $X_H = +1$

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1. Factors influencing air density (3 points)

Consider ambient air. For each part of this problem, one parameter is changed in the direction noted. All other parameters remain fixed at their baseline conditions: P = 1 atm, T = 293 K, RH = 50%. State how the change would affect the air density: would it increase, decrease or stay the same? Briefly justify your answers.

(a) Increase the temperature.
(b) Increase the pressure.
(c) Increase the relative humidity.

2. An acid-base, phase partitioning, equilibrium problem (6 points)

Consider a batch reactor that contains volumes V_w of pure water and V_a of pure gaseous nitrogen. To this reactor is added a quantity of M moles of solid calcium carbonate ($CaCO_3$), which completely dissolves into calcium (Ca^{2+}) and carbonate (CO_3^-) ions. As we know, other species in the carbonate system will be generated, including bicarbonate (HCO_3^-), carbonic acid ($H_2CO_3^*$), and gaseous carbon dioxide (CO_2 (g)). To solve for equilibrium pH, we must set up a system of equations sufficient to solve seven unknowns: $[Ca^{2+}]$, $[CO_3^{2-}]$, $[HCO_3^-]$, $[H_2CO_3^*]$, $[OH^-]$, $[H^+]$, and P_{CO2}. There are four equilibrium relationships that link them: Henry's law, two acid-base reactions, and the dissociation of water. The electroneutrality relationship provides a fifth equation.

(a) Write the two other equations that complete the mathematical specification of this problem (4 points).
(b) Will the equilibrium pH be *higher* than 7.0, *lower* than 7.0, or *equal* to 7.0. Explain briefly (2 points).

3. Kinetic characteristics of a chemical reaction (6 points)

In a batch reactor, the following reaction occurs:

reaction:	$A + B \rightarrow$ products
rate law:	$R = k[A]$
initial conditions:	$[A](0) = A_o$ $[B](0) = B_o$ $B_o << A_o$

(a) Write differential equations describing the rates of change of [A] and [B]. (2 points)
(b) What is the characteristic time for this reaction to proceed to completion? (2 points)
(c) What are the final, steady-state concentrations of [A] and [B]? (2 points)

4. Dissolved oxygen can be a pollutant (5 points)

In industrial boilers, dissolved oxygen can be a potent corrosive agent, causing iron to rust. Write a stoichoimetrically balanced reaction in which Fe(s) is converted to Fe^{3+} in water with dissolved oxygen (O_2) as the oxidizer.