Analytical Chemistry Cumulative Examination

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1. (30 pts) An important aspect of analytical chemistry concerns the propagation of errors in measurements. A systematic approach to this problem involves a straightforward application of calculus. If *u(x,y,z)* is a function of *x*, *y*, and *z*, then the spread in *u* determined by a given spread in *x*, *y*, and *z* of Δx, Δy, and Δz is given by

$$\Delta u = \sqrt{\left(\frac{\partial u}{\partial x}\right)^2_{y,z} (\Delta x)^2 + \left(\frac{\partial u}{\partial y}\right)^2_{x,z} (\Delta y)^2 + \left(\frac{\partial u}{\partial z}\right)^2_{x,y} (\Delta z)^2}$$

a) (15 pts) Suppose a physical quantity, u, is related to measurable quantities *x*, *y*, and z by the equation

$$u = x+y+z$$

and that the measured values of *x*, *y* and *z* along with their uncertainties, Δx, Δy, and Δz, are 3.25 ± 0.03, 10.60 ± 0.02, and 7.60 ± 0.08, respectively. Give the value of *u* along with its uncertainty.

b) (15 pts) Suppose a researcher wanted to estimate the radius of a Xe atom from the crystal structure of solid xenon determined at 58 K, which yields an average volume per atom of 80.36 ± 0.05 $Å^3$. The volume of a sphere is given by $V = (4/3)\pi r^3$. If the relative uncertainty in the volume, $\Delta V/V = 0.05/80.36 = 6x10^{-4}$, what is the relative uncertainty of the radius, $\Delta r/r$?

2. (30 pts) In using analytical instruments, a basic understanding of electricity is important.

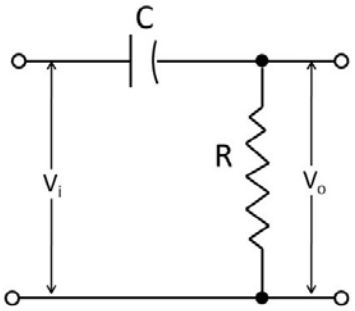
a) (10 pts) State Ohm's law. Define all quantities.

b) (10 pts) Give an expression for the power dissipated in a circuit with a current *I* and a voltage *V*.

c) (5 pts) What is the equivalent resistance, R_{eq}, of three resistors, of resistances R_1, R_2, and R_3, arranged in series.

d) (5 pts) What is the equivalent resistance, R_{eq}, of three resistors, of resistances R_1, R_2, and R_3, arranged in parallel.

3. (40 pts). High pass electronic filters are very common in analytical instruments that involve time dependent voltages. The figure below shows an equivalent circuit for a high pass filter.



a) (15 pts) For ac circuits, the effective resistance governing the relationship between peak values of the current and the voltage is referred to as the impedance, Z, which for this circuit is given by

$$Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

where R is the resistance, C is the capacitance, and ω is the frequency of the input voltage, V_i. Find the ratio of the peak values of the output voltage to the peak value of the input voltage, i.e., find (V_o/V_i). Assume that the current going through the capacitor continues through the resistor.

b) (15 pts) Give an expression for the frequency at which the output voltage is half of the input voltage.

c) (10 pts) The international system of units, abbreviated as SI (from the French name Le Systèm International d'Unités), uses seven base units for the physical quantities of length, mass, time, electric current, temperature, amount of substance, and luminous intensity. The following table summarizes these SI units.

Base Quantity	SI Name	SI Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Although resistance and capacitance are conventionally given in terms of Ohms and Farads, these quantities, as well as the impedance, can be expressed in terms of the SI base units. Give expressions for R, C, and Z in terms of SI base units.