Useful data: R = 0.082 L atm/(mol K) or 8.3145 J/(mol K), h (Planck's constant) = 6.626×10^{-34} J s, m_e (mass of an electron) = 9.11×10^{-34} kg, c (speed of light) = 3.0×10^{8} m/s. Atomic mass: H, 1.00; C, 12.00; O, 16.00, Ti: 47.88

It is important to show the derivation in solving the problems. You gain NO score if only the answer is given.

1. The normal boiling point of 1-butanol is 117.8°C and the enthalpy of vaporization for 1-butanol is $\Delta H° = 43.82$ kJ/mol at 1 atm. Calculate the boiling point of 1-butanol when the barometric pressure is 570 mmHg. 10%
2. Calculate E_{cell} for the following voltaic cell. $K_b = 1.8\times10^{-5}$ for NH_3
   $Pt|H_2$ (g, 1 atm)$|H^+$ (0.010M)$||NH_3$ (0.30M), NH_4^+(0.15M)$|H_2$ (g, 1 atm)$|Pt$ 10%
3. Solid Mo is kept in contact with only CH_4, initially at a pressure of 2.00 atm, in the following reaction at 973K: $2Mo_{(s)} + CH_{4(g)} \rightarrow Mo_2C_{(s)} + 2H_{2(g)}$, ($K_P = 3.55$). Calculate (a) the pressure of H_2 and (b) the total pressure when equilibrium is established. 10%
4. A steel cylinder contains 5.00 mol of graphite (pure carbon) and 5.00 mol of O_2. The mixture is ignited and all the graphite reacts. Combustion produces a mixture of CO gas and CO_2 gas. After the cylinder has cooled to its original temperature, it is found that the pressure of the cylinder has increased by 21%. Calculate (a) total mole of CO, CO_2 and O_2 (b) the mole fractions of CO, CO_2 and O_2 in the final gaseous mixture. 10%
5. The pH value of a 0.050 M solution of the salt NaX is 10.02, indicating that HX is a weak acid. Calculate (a) K_a of HX and (b) the pH value of a 50.0 mL 0.10M solution of this weak acid HX. After addition of 15.0 mL of 0.250 M KOH into the solution in (b), (c) find the pH value of the solution? 10%
6. A certain oxide of titanium is 28.31% oxygen by mass and contains a mixture of Ti^{2+} and Ti^{3+} ions. Determine the formula of the compound and the relative percentage of Ti^{2+} and Ti^{3+} ions. 10%
7. The treatment of a particle in a two-dimensional box of dimensions L_x and L_y yields the following expression for energy. The two quantum numbers n_x and n_y independently can assume only integer values. Consider an electron confined to a 2-dimensional box that is 8.00 nm in the x-direction and 4.00 nm in the y direction. (a) What are the quantum numbers for the first four allowed energy levels (from the lowest state)? (b) Calculate the wavelength of light necessary to promote an electron from the second excited state to the third excited state.

   $$E = \frac{h^2}{8m}\left\{\frac{n_x^{\ 2}}{L_x^{\ 2}} + \frac{n_y^{\ 2}}{L_y^{\ 2}}\right\} \qquad 10\%$$

8. A 1.405 g sample of an alkane yields 4.305 g CO_2 and 2.056 g H_2O on combustion. A 0.403 g sample of this gaseous hydrocarbon occupies a volume of 145 mL at 99.8°C and 749 mmHg. (a) What is the empirical formula (b) Find the molecular formula. (c) Draw structural formulas for all the possible isomers that fit this description 10%
9. For a reaction: aA → products, obeying the first-order rate law kinetics, the rate law can be defined as $Rate = -d[A]/dt = k[A]$. If the reaction is second order in A, the rate law can be defined as $Rate = -d[A]/dt = k'[A]^2$. Derive the integrated first-order and second-order rate law. For the data listed below obtained from a specific reaction, determine the rate order, rate constant and half life of the reaction. 10%

[A] in mol/L	0.01000	0.00625	0.00476	0.00370	0.00313	0.00270	0.00241	0.00208
Time in sec	0	1000	1800	2800	3600	4400	5200	6200

10. Draw the d-orbital splitting diagrams for the octahedral complex ions of each of the following. (a) Fe^{2+} (high and low spin) (b) Fe^{3+} (high spin) (c) Co^{2+} (high and low spin). Tetrahedral complexes of Co^{2+} are also quite common, (d) Rationalize the stability of these complexes using the d-orbital splitting diagram. 10%