

- 1) An atom makes a transition from an excited state with a lifetime of  $10^{-9}$  s to the ground state and emits a photon with wavelength 600 nm. What is the uncertainty in the energy of the excited state? What is the percentage uncertainty if the energy is measured from the ground state?

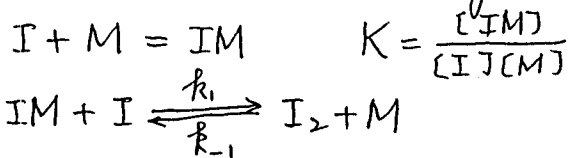
Note: Planck constant  $h = 6.626 \times 10^{-34}$  Js. (14%)

- 2) (a) Calculate the energy levels for  $n=1$  and  $n=2$  for an electron in a potential well of width 0.5 nm with infinite barriers on either side. The energies should be expressed in  $\text{kJ mol}^{-1}$ . (b) If an electron makes a transition from  $n=2$  to  $n=1$ , what will be the wavelength of the radiation emitted?

Note: Mass of electron is  $9.11 \times 10^{-31}$  kg. (14%)

- 3) Suppose that in an industrial batch process a substance A produces the desired product B which goes on to decay to a worthless product C, each stage of the reaction being first-order. At what time will product B be present in greatest concentration? (10%)

- 4) The apparent activation energy for the recombination of iodine atoms in argon is  $-5.9 \text{ kJ mol}^{-1}$ . This negative temperature coefficient may result from the following mechanism.



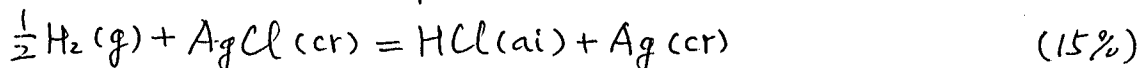
Assuming that the first step remains at equilibrium, derive the rate equation that includes both the forward and reverse reactions. Show that the reverse reaction is bimolecular and the equilibrium constant expression for the dissociation of iodine is independent of the concentration of the third body. (12%)

- 5) A mole of steam is condensed at  $100^\circ\text{C}$  and the water is cooled to  $0^\circ\text{C}$  and frozen to ice. What is the entropy change of the water? Consider that the average specific heat of liquid water is  $4.2 \text{ J K}^{-1} \text{ g}^{-1}$ . The heat of vaporization at the boiling point and the heat of fusion at the freezing point are  $2258.1$  and  $333.5 \text{ J g}^{-1}$ , respectively. (11%)

- 6) The standard electromotive force of the cell  $\text{Pt} | \text{H}_2(\text{g}) | \text{HCl}(\text{aq}) | \text{AgCl}(\text{cr}) | \text{Ag}$  has been determined from 0 to  $90^\circ\text{C}$  by R. G. Bates and V. E. Bower. Their data may be represented by:

$$\frac{E^\circ}{V} = 0.23659 - 4.8564 \times 10^{-4} \left(\frac{T}{^\circ\text{C}}\right) - 3.4205 \times 10^{-6} \left(\frac{T}{^\circ\text{C}}\right)^2 + 5.869 \times 10^{-9} \left(\frac{T}{^\circ\text{C}}\right)^3$$

What are  $\Delta G^\circ$ ,  $\Delta H^\circ$ , and  $\Delta C_p^\circ$  at  $25^\circ\text{C}$  for the reaction



- 7) The following cooling curves have been found for the system antimony - cadmium.

Cd, wt%                      0    20    37.5    47.5    50    58    70    93    100

First break in curve,  $^\circ\text{C}$         -    550    461    -    419    -    400    -    -

Continuing constant temp,  $^\circ\text{C}$     630    410    410    410    410    439    295    295    321

Construct a phase diagram, assuming that no breaks other than these actually occur in any cooling curve. Label the diagram completely and give the formula of any compound formed. How many degrees of freedom are there for each area and at each eutectic point? Given: Atomic weight,  $\text{Sb} = 121.75$ ,  $\text{Cd} = 112.40$

(12%)

- 8) Water vapor is rapidly cooled to  $25^\circ\text{C}$  to find the degree of supersaturation required to nucleate water droplets spontaneously. It is found that the vapor pressure of water must be four times its equilibrium vapor pressure at  $25^\circ\text{C}$ . (a) Calculate the radius of a stable water droplet formed at this degree of supersaturation. (b) How many water molecules are there in the droplet? The surface tension of water at  $25^\circ\text{C}$  is  $71.97 \times 10^{-3} \text{ N m}^{-1}$ . (12%)