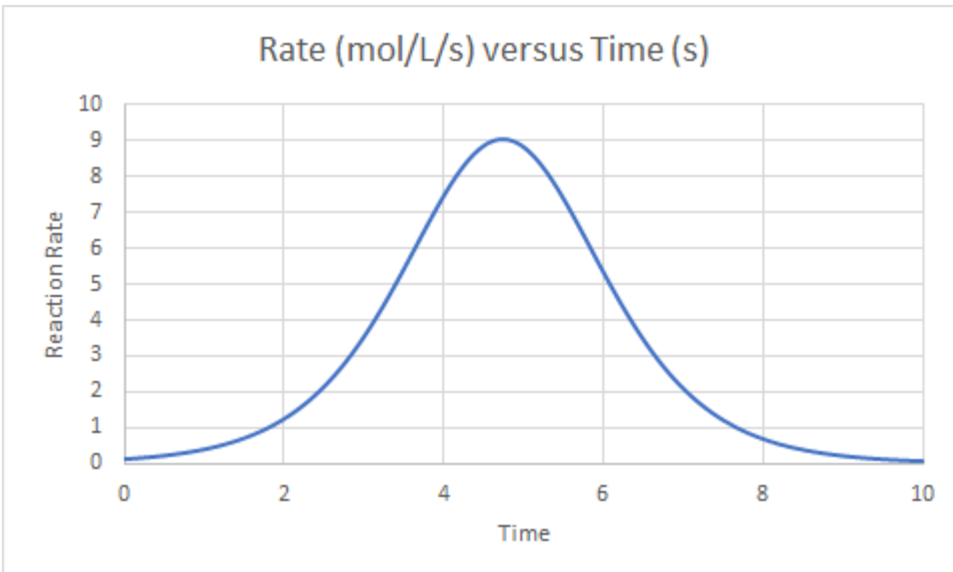
WUCT: Team Exam Sample Question

1. Autocatalysis is a process by which a small amount of reactant is able to catalyze another reactant to form twice the amount of catalyst. The general overall reaction is represented below:

$$A + B \rightarrow 2B$$

B catalyzes A into B. One real life example of this is the conversion of β-Tin to α-Tin via an autocatalytic, allotropic transformation. α-Tin, known as tin pest, is able to convert β-Tin into more α-Tin. This process usually begins with a small conversion to α-Tin at a corner of a sheet of β-Tin and subsequently leads to expansion of α-Tin via autolytic conversion.



a. The graph above displays the reaction rate of the general equation presented above. Describe the general curvature the graph assumes in context to the reaction. Specifically, focus on the catalysis of A by B.

b. Write two differential rate laws with respect to the loss of A and the production of B. Assume the rate constant to be **k** and the reaction to follow an elementary mechanism.

c. There are three primary phases of an autocatalytic reaction: lag, log and stationary. Will the autocatalytic reaction have multiple rate constants or a single rate constant? Explain.

2. Electrons have both particle and wave-like behavior. The particulate behavior of electrons can be described by De Broglie's equation relating momentum and wavelength.

$$p = \frac{h}{\lambda}$$

Where $p =$ mv (mass times velocity), h is Planck's constant ($6.626 \cdot 10^{-34}\ Js$), and λ represents the wavelength.

a. Describe what happens to the momentum as the wavelength decreases. How does this relate to the frequency of the wave and the kinetic energy?

b. Given the mass of an electron is $9.11 \cdot 10^{-31}\ kg$ and is moving at 70% the speed of light ($c = 3.0 \cdot 10^{8}\ {}^{m}/_{s}$), what is the momentum, wavelength and frequency (Hz) of the electron?

c. A baseball weighs 0.145 kg and is moving at a velocity of 40 m/s. Calculate the wavelength of the baseball. The correspondence principle states that we can reproduce quantum mechanical phenomena on a classical scale upon the increase of the principal quantum number. In context to the correspondence principle, compare the wavelength of a baseball and an electron and why we don't observe baseballs "teleporting" from one location to another.

d. Heisenberg's uncertainty principle states that we cannot measure both position and momentum with absolute precision in a quantum mechanical system. If we know that the momentum of a particle in free space is known with absolute precision, what is the probability of finding the particle at a certain location in space? What is the probability of finding the particle in all space?

e. The wavelike characteristics of quantum mechanical particles is often encapsulated within wavefunctions. Wavefunctions describe the probability of finding a particle in a certain location. The wavefunction for a particle on a ring (a fundamental model for simplifying the hydrogen atom) is presented below. The probability of a particle being somewhere in space can be described by multiplying the wavefunction by its complex conjugate. A complex conjugate simply inverses any complex numbers (i becomes -i and vice versa). Given the wavefunction, describe the probability of the particle in space. What does this tell us about the angular momentum of the particle?

$$\psi(\phi) = \left(\sqrt{\frac{1}{2\pi}}\right) e^{im\phi}$$