Quiz 1 solutions

1. (3 points) Please explain the conceptual difference between heat (q) and internal energy (U), i.e. what is heat energy and what is internal energy?

Heat is a form of energy without mass and cannot be transformed/converted into other forms of energy at 100% efficiency. Internal energy is energy contained by mass in the form of molecular kinetic energy (vibration, rotation, translation) and atomic/molecular interactions (intermolecular attraction/repulsion, chemical bonds).

1. (2 points) There are many forms of energy, e.g. electrical, radiation, heat, internal, kinetic, potential, etc. Please briefly explain conceptually why heat is considered the least useful form of energy from an engineering perspective.

All other forms of energy can be converted into heat at 100% efficiency. Heat cannot be converted at 100% efficiency into other forms of energy.

1. (2 points) The 1st law (conservation of mass) can be generally described in words as ‘input – output + generation – depletion = accumulation”. It is also said that mass cannot be created or destroyed (ignoring nuclear physics). So please explain why there are generation and depletion terms in the general mass balance equation?

The statement that mass cannot be created/destroyed is true for total mass balances. The generation/depletion terms in the general mass balance are related to component mass balances, where chemical reactions occur that create/destroy specific chemical species. Chemical reactions do not affect total mass, they just re-arrange atoms into different molecules.

1. (2 points) Chemical reaction rates generally change with temperature (T) and concentration (C). Please explain conceptually why.

The fundamental concept of chemical reaction rate involves the frequency of collisions of molecules containing sufficient kinetic energy to transform the chemical bond interaction energies between atoms into new forms (e.g. new chemical species, heat, electricity, etc.). The concentration affects the frequency of collisions and the temperature affects the kinetic energy of the molecules, hence both affect the rate of chemical reaction.

1. (2 points) Newton’s model for fluid flow is written as  = - \*dV/dx. Please briefly explain conceptually what shear stress () is with respect to the movement of fluids.

Shear stress has dimensions of force/area, the same as pressure. Just like pressure, shear stress causes the movement of fluids. However, movement caused by pressure is in the same direction as the applied pressure, i.e. pushed forward. Movement caused by shear is in the orthogonal direction to the applied shear stress, i.e. sheared forward.

1. (2 points) In your simple proportional transport models ( = - \*dV/dx, q = - k\*dT/dx, j=-*D*\*dC/dx), the flow direction of transported quantities are from high to low, e.g. high temperature to low temperature, high concentration to low concentration, high velocity to low velocity). Please explain why.

Entropy controls the spontaneous movement of processes, which always results in a higher entropy value in the final state vs. the initial state. In all the cases noted, the ‘high’ state contains lower entropy (higher potential/structure/utility) than the ‘low’ state, hence entropy causes the direction of flow of the transported quantities.

1. (3 points) Living systems generally operate by enzymatic reactions vs. purely chemical reactions and therefore have a different kinetic reaction rate model. The Michelis-Menten rate model is hyperbolic vs. 1st order model reaction). Comparing reaction rate(r) vs. reactant concentration (S), the M-M reaction rate kinetic model is hyperbolic vs. linear behavior for a 1st order reaction. Please explain why this might make sense for a living/biological system.

A 1st order rate model is proportional to the concentration of the reactant. This means at low reactant concentration the rate is low, meaning living systems will not exhaust reactants completely. However, at high concentrations the rate continues to increase indefinitely. This would not be good for living systems. The hyperbolic enzymatic rate model has the same behavior at low reactant concentrations but as the reactant concentration increases, the reaction rate slows and reaches a maximum value, hence the reaction rate is controlled. Much better control for a living system to avoid out of control reactions!

1. (3 points) The natural parameters of enthalpy (H) are entropy and pressure, i.e. dH = VdP+TdS or H is a function of (S, V). This makes H useful in evaluating the thermodynamic efficiency of heat/work processes (e.g. pistons/engines) since its natural parameters are pressure (P) and entropy (S). Gibbs energy is a natural function of T and P, i.e. dG = VdP – SdT, as defined for a single, pure material. Gibbs energy is very useful for evaluation of chemical reactions and biological systems. Please explain why. (Possibly helpful hint: what happens in chemical reactions that affects internal energy changes or under what conditions do biological systems exist?)

Living systems exist at constant P and T and operated energetically by obtaining useful forms of energy from chemical reactions/chemical concentration gradients. For mixtures, dG = VdP – SdT + dNi, where Ni is the molar amount and  is the chemical potential. At constant T, P, dG = dNi, which is simply a statement of energetic changes based on changes of composition, i.e. chemical reactions.

1. (1 point) Under what circumstances will make-up quizzes be given?

Prior excused absence or campus emergency

1. (1 point) What is the purpose of the 1st project deliverable and what is the deliverable to contain?

The purpose of the 1st deliverable is to select a project topic. It should contain a brief 1-2 page description of your topic, including relevant pictures/proposed system definition/relevant parameters/modeled parameters

1. (3 points) According to the syllabus, when should you begin working on your project?

Today

1. (1 point) Under what circumstances may you drop your lowest quiz score for the course?

As long as you have completed/turned in all project assignments on time.