







11. What is the change in the amplitude of vibration if the molecule transitions from the ground vibrational state to the first excited vibrational state?

You shine continuous IR light on atomic Hydrogen gas and study the light that gets absorbed by the gas.

12. Which are the four lowest energy photons that will be absorbed by atoms that are in the second excited state?

13. What energy is required to ionize a hydrogen atom that is in the second excited state?

14. What happens to a 0.4-eV photon that is incident on the gas?

# Answer Key for Exam A

## Section 1. Thermal Energy

1.  $\Delta E_{Al} = mC\Delta T = 90 \text{ J}$

$$\Delta E_{Cu} = mC\Delta T = 58.5 \text{ J}$$

Therefore, Al gains more energy.

2.  $\Delta E_{therm}$  is due to a change in temperature or phase for the system. Even a closed system can have a change in thermal energy.  $Q$  is due to energy transferred by thermal means, via conduction or radiation for example, from the surroundings to the system. If  $Q$  is not 0, then the system is definitely an open system.  $Q$  may be transferred to the system even if the system's thermal energy does not change.

3. Define the system to be the child, earth, and slide. Neglect the force of air on the system and neglect energy transferred thermally to the system. Thus,  $W = 0$  and  $Q = 0$ .  $\Delta E = W + Q$   
 $\Delta K + \Delta U_{grav} + \Delta E_{int}$  where the change in internal energy includes chemical energy and thermal energy changes in the system.

$$0 + mg\Delta y + \Delta E_{int} = 0$$

$$\Delta E_{int} = -mg\Delta y = -(20)(9.8)(-1.5) = 294 \text{ J}$$

4. Define the system to be the child, earth, and slide. Neglect the force of air on the system and neglect energy transferred thermally to the system. Thus,  $W = 0$  and  $Q = 0$ .

$$\Delta E = W + Q$$

$\Delta K + \Delta U_{grav} + \Delta E_{int}$  where the change in internal energy includes chemical energy and thermal energy changes in the system.

$$1/2mv_f^2 - 1/2mv_i^2 + mg\Delta y + \Delta E_{int} = 0$$

$$\Delta E_{int} = -1/2mv_f^2 + -mg\Delta y = -40 + -(20)(9.8)(-1.5) = 254 \text{ J}$$

5. Define the system to be the object, air, and earth. Neglect external forces and energy transferred to or from the system via thermal mechanisms ( $W = 0$  and  $Q = 0$ ).

$$\Delta E = W + Q$$

$\Delta K + \Delta U_{grav} + \Delta E_{therm}$  where the change in thermal energy includes the air and object.

$$1/2mv_f^2 - 1/2mv_i^2 + mg\Delta y + \Delta E_{therm} = 0$$

$$\Delta E_{therm} = -1/2mv_f^2 + -mg\Delta y = -0.8 + 49 = 48.2 \text{ J}$$

6.

$(0.5)(48.2) = 24.1 \text{ J}$ , the change in thermal energy of the object

$$\Delta E_{object} = mC\Delta T = 0.482$$

$$\Delta T = \frac{24.1}{(100 \text{ grams})(1.1 \text{ J/gram/K})} = 0.22^\circ\text{C}$$

## Section 2. Quantized energy states

7. Electronic energy is the energy associated with the electrons' configuration and ave distance from the nuclei.

Vibrational energy is the energy associated with vibration/oscillation–spring potential energy ( $1/2kA^2$ ).

Rotational energy is the energy associated with rotational motion.

8.  $E = N\hbar\omega_0 + E_0$  where  $E_0 = 1/2\hbar\omega_0$

$$E_0 = 1/2\hbar\sqrt{k/m} = 1/2(6.56 \times 10^{-16})(6.928 \times 10^{14}) = 0.227 \text{ eV}$$

$$E_1 = 3/2\hbar\omega_0 = 0.682 \text{ eV}$$

9.  $E = 1/2kA^2$

$$A = \sqrt{\frac{2E}{k}} = \sqrt{\frac{2(0.227)(1.6e-19)}{480}} = 1.23 \times 10^{-11} \text{ m for } E_0 \quad A = 2.13 \times 10^{-11} \text{ m for } E_1$$

10.  $\Delta E = E_1 - E_0 = 0.455 \text{ eV}$  which is in the infrared region of the spectrum.

11.  $\Delta A = 0.9 \times 10^{-11} \text{ m}$  which is approximately 73% of  $A_0$ . Thus,  $A$  increases by 73% due to the absorption of the photon.

12.  $\Delta E_{4-3} = -0.86 - (-1.51) = 0.65 \text{ eV}$

$$\Delta E_{5-3} = -0.54 - (-1.51) = 0.97 \text{ eV}$$

$$\Delta E_{6-3} = -0.378 - (-1.51) = 1.13 \text{ eV}$$

$$\Delta E_{7-3} = -0.278 - (-1.51) = 2.23 \text{ eV}$$

13.  $E_3 = -1.51 \text{ eV}$

The energy required to ionize the atom is the minimum energy required to strip the electron so that it can be separated an infinite distance away and not be moving. This energy state is  $E = 0$ . The change in energy required is  $0 - (-1.51) \text{ eV}$ , or  $1.51 \text{ eV}$ .

14. Nothing. It just passes through the gas and is not absorbed because it does not correspond to a change in energy between any two energy states for H. For example,

$$\Delta E_{2-1} = 10.2 \text{ eV}$$

$$\Delta E_{3-2} = 1.9 \text{ eV}$$

$$\Delta E_{3-1} = 12.1 \text{ eV}$$

Transitions from  $N=1$  a higher level are all bigger than  $4 \text{ eV}$ . Transitions from  $N=2$  to higher levels are all less than  $4 \text{ eV}$ . Transitions from  $N=3$  to higher levels are all less than  $4 \text{ eV}$ .