03 Thermal physics review **answers**

Part A: Thermal Concepts:

1. In the phrase "two objects in thermal equilibrium….." what does this mean and what does it tell you about the two objects? **Same temperature**
2. The Celsius scale is defined as being a centigrade (100 intervals) between the ice point of water and the steam point of water. How is the Kelvin scale defined?
   Zero is absolute zero, One degree change is same as one degree Celsius change
3. The symbol U is used to denote internal energy of an object. This energy is contained within the individual particles of the object in which forms?
   Kinetic and potential energy
4. Choose between the words "thermal, internal, kinetic, potential" to fill in these three gaps. "When **thermal** energy is transferred to a pot of ice and water the ice melts so the **potential** energy of the water particles increases. When **thermal** energy is transferred a the pot of cold water the particles move quicker so the **kinetic** energy of the water particles increases. In both of these situations the **internal** energy of the water increases.
5. Water has a molar mass of $18gmol^{-1}$. How many water molecules are there in $1cm^3$ of water (Water density = $1000kgm^{-3}$)?
   $1cm^3$ = 1g = 1/18 mol = $6.02x10^{23}$/18 particles = $3.34x10^{23}$ particles.

Part B Thermal Properties of matter (Heat capacities etc..)

Data: Specific heat capacity, ice = 2.11 $kJkg^{-1}K^{-1}$
Specific heat capacity, water = 4.19 $kJkg^{-1}K^{-1}$
Latent heat of melting of ice = 334 $kJkg^{-1}$
Latent heat of evaporation of water (at atmospheric pressure) = 2.27 $MJkg^{-1}$

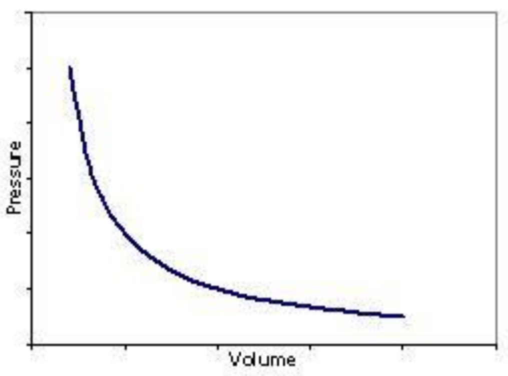
[Ignore heat exchanges with containers or the surroundings in these questions]

1. Explain the term phase change and state the four phases of matter.
   Change of state of matter – Solid, Liquid, Gas, Plasma
2. Give two differences between evaporation and boiling.
   Boiling occurs at a specific temperature and throughout a liquid, evaporation occurs only on surface of a liquid and over a range of temperatures
3. Explain in terms of bonds why the latent heat of evaporation of water is much greater than the latent heat of melting of ice. (HL students can give another reason)
   More bonds are broken during evaporation compared to melting.(Gas takes up more space and expansion requires work to be done)
4. How much heat is required to warm 1.0 kg ice initially at -10 ºC to ice at 0 ºC? How much heat is required to melt the ice at 0 ºC? How much heat is required to further increase the temperature of the water from 0 ºC to 10 ºC? In which stage (warming the ice, melting the ice, warming the water) is the heat required the largest?
   Warming ice: 21.1kJ, Melting it: 334 kJ, Warming it: 41.9kJ (Melting)
5. Radiation from the sun falls on the frozen surface of a pond at a rate of 600 Wm^{-2}. If the ice temperature is 0 ºC, find how long it will take to melt a 1.0 cm thick layer of ice. (Take the density of ice to be 900 kgm^{-3}.)
   For $1m^2$ ice: Q = mL so in 1 second $600/334x10^3$ = $1.796\ x10^{-3}$ kg.
   Mass = density x volume = 900 x 0.01 = 9kg.
   $9/1.796x10^{-3}$ = 5000 seconds.

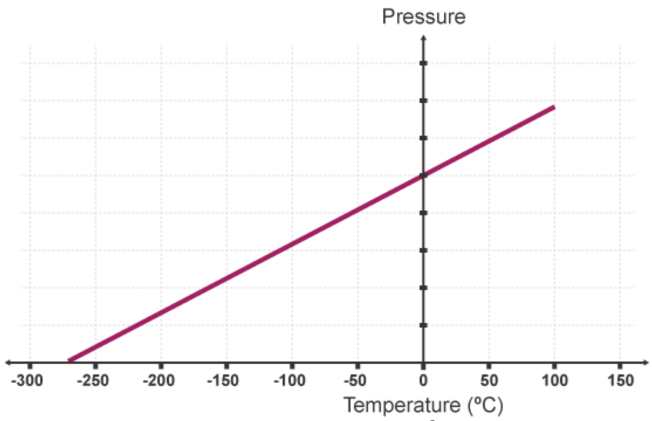
6. The surface of a pond of area 20 m² is covered by ice of uniform thickness 6 cm. The temperature of the ice is -5 ºC. How much heat is required to melt this amount of ice into water at 0 ºC? (Take the density of ice to be 900 kg m^{-3}.)
   Q = mCΔT + mL = m(CΔT + L)
   m = density x volume = 900 x 0.06 x 20 = 1080kg
   Q = 1080(2.11x10^3x5 + 334x10^3) = 3.72x10^8 J
7. Crushed ice at 0 ºC is added to one litre of water at 20 ºC. While mixing the ice melts and the mixtures final temperature is 10 ºC. How much ice was added? **Heat gained by ice = Heat lost by water: (ΔT= 10, m_w=1kg)**
   m x 4.2 x 10 + m x 334 = 1 x 4.2 x 10
   m = 42/(42+334) = 0.11kg
8. A 200g piece of metal at 100ºC is added to a container which has 150 g water at 15ºC. The final temperature inside the container is 35 ºC. What is the specific heat capacity of the metal?
   0.2 x C x 65 = 0.15 x 4.2 x 20
   C = (0.15 x 4.2 x 20)/(0.2 x 65) = 0.97 kJ$kg^{-1}K^{-1}$
   Note that for all of above working kJ have been used.

Part B Thermal Properties of matter (Kinetic model of an ideal gas)

1. Define pressure and explain how a gas exerts a seemingly constant pressure on a surface.
   Force applied per unit area of surface. There are so many collisions between gas particle and a surface that the effect is like a continuous force.
2. The ideal gas model makes three assumptions about the behaviour of the particles.
   a. What are they?
   Point particles (no size), No intra-particle force (no bonding) and Completely elastic collisions.
   b. Two of these assumptions are false, which ones?
   The first two.
   c. Despite these false assumptions explain why, at temperatures well above boiling point and relatively low pressures, the ideal gas model can be used to approximate the behaviour of real gases. Why is this?
   The particles are well spread so their size is unimportant, they have enough kinetic energy that the intra-particle forces do not significantly change their behaviour.
   d. i)Explain why reducing the volume of a gas increases the pressure.
   More collisions occur.
   ii) Sketch a graph of pressure vs. volume for a fixed amount of an ideal gas



   e. i) Explain why reducing the temperature of a gas decreases the pressure.
   Reducing the temperature means reducing the average Ek of the particles meaning they are slower so each collision gives a smaller impulse making the pressure less.
   ii) Sketch a graph of pressure vs. temperature (ºC) for a fixed volume of an ideal gas.



iii) Does volume vs temperature(^{o}C) for an ideal gas at fixed temperature follows the shape of graph dii or eii?

e.ii).

3. A SCUBA* diver is deep underwater.
   The pressure is 2.03×10^5 Pa and the temperature is 10 ^{o}C.
   The volume of her lungs is $3.0\text{x}10^{-3}$ m^3
   a. Approximately how many moles of air are in her lungs?
      pV = nRT
      p = 2.03×10^5 Pa, V = $3.0\text{x}10^{-3}$ m3, T = 273+10 = 283K
      Gas constant R 8.31JK^{-1}mol^{-1}
      n = pV/RT = 2.03×10^5 x $3.0\text{x}10^{-3}$ / (283 x 8.31)
      = 0.259 moles
   a. If she rises to a place where the pressure is 1.76×10^5 Pa and does not breath out what is the new volume in her lungs?
      V = nRT/p = 0.259 x 8.31 x 283 / 1.76×10^5 = $3.46\text{x}10^{-3}$m^3.
      Or
      $V_2 = P_1/P_2 * V_1 = 2.03/1.76 * 3.0\text{x}10^{-3}$ m^3 = $3.46\text{x}10^{-3}$m^3.

Extra one:

A block of metal of mass 0.5kg, temperature 600K, and specific heat capacity 1.7 kJkg^{-1}K^{-1}. Is placed into a bath of water of mass 4kg, temperature 300K and specific heat capacity 4.2 kJkg^{-1}K^{-1}. Calculate the final temperature of the water and the metal. State any assumptions you are making to arrive at your answer.

mCΔT = mCΔT (assumes no heat loss)
0.5x1.7x(600-T) = 4x4.2x(T-300)
510 - 0.85T = 16.8T – 5040
5550 = 17.65T → T = 314K