**Chapter 14**
**Multiple choice and quick questions**

1. What is the order in increasing energy of the three particles in the situations listed below?

   1: K.E. of an electron accelerated through 30 volts

   2: K.E. of an air molecule at room temperature

   3: K.E. of an alpha-particle emitted from the nucleus of an atom increasing energy

   **A** 2 3 1 **B** 2 1 3 ✓ **C** 1 2 3

   **D** 1 3 2 **E** 3 2 1

2. In a certain chemical reaction, pairs of particles only combine when they collide with an energy greater than $E$. When the temperature $T$ is 300 K, $E$ is about 10 times the average energy $kT$ of the particles.

   Which one of the following is a good way of estimating how much faster the reaction goes at 330 K compared with 300 K?

   The arithmetic is correct in each case, but in only one is the argument correct.

   **A** about 5% faster, because the average speed of the particles has increased by about this amount

   **B** about 10% faster, because the average energy $kT$ of the particles has increased by 10%

   **C** about 2.5 times faster, because $e^{-E/kT}$ has increased by about 2.5 times ✓

   **D** about 3 times faster, because

   $$\frac{330-300}{E/T}$$

   is about 3, where $T$ is the average of 300 and 330

   **E** about 10 times faster, because $E/kT$ is still close to 10

3. An experimenter records the values of the current $I$ in a thermistor at various temperatures $T$. The experimenter wishes to test the relationship:

   $I \propto P\, e^{-A/T}$ where $A$ and $P$ are constants

   If the relationship is correct, which quantities should be plotted to obtain a straight line?

   **A** $I$ against $1/T$

**B** 1/*I* against 1/*T*

**C** *I* against 1n*T*

**D** 1n*I* against *T*

**E** 1n*I* against 1/*T* ✓

4. In a new design for a power station the predicted maximum thermodynamic efficiency is 60% when the surroundings are at 300 K. Which one of **A** to **E** below gives the assumed temperature of the energy source?

**A** 18000K **B** 1800 K **C** 750K ✓ **D** 500 K **E** 450 K

5. The energy, *e*, required for a water molecule to go from the liquid into the vapour is about 3 x $10^{-20}$J.

(a) Calculate the Boltzmann factor $e^{-e/kT}$ for the vaporisation of water at 300 K.

$= e^{-3 \times 10^{-20} / 1.38 \times 10^{-23} \times 300}$

= 7.25

Boltzmann factor = 7.25

(b) State the units of the quantity *kT*

Unit kT
= J $K^{-1}$ x K
= J

Units = J………

6. In a mixture of particles which are in equilibrium at temperature *T*, the particles will have various energies; the number $n_{low}$ having a certain energy *E* and the number $n_{high}$ having energy $E + \Delta E$ are related by the formula (A) below:

$$\frac{n_{high}}{n_{low}} = e^{\frac{-\Delta ?}{kT}} \quad ................(A)$$

where *k* is the Boltzmann constant.

This question is concerned with how the formula might be applied to the molecules in the Earth's atmosphere.

(a) Write down an expression for the difference *DE* in gravitational potential energy of a molecule of mass *m* at ground level and the same molecule raised to a small height *h* above the Earth's surface:

$\Delta E = m \text{ x } g \text{ x } h$

(b) Now rewrite the formula (A) in terms of:

- the energy difference you have given at (a)
- the number of molecules per unit volume $n_o$ at the Earth's surface
- the number of molecules per unit volume $n_h$ at height *h* in the Earth's atmosphere.

$$\frac{n_h}{n_o} = e^{-mgh/kT}$$