Thermal Physics-1

Exercise A

1 Explain why it is not possible to achieve a temperature lower than 0 K. *(1 mark)*

2 Describe what happens to the energy transferred to a substance being heated when it changes phase. *(2 marks)*

3 State two ways to increase the internal energy of a substance. *(2 marks)*

4 Explain why 1.0 kg of water at 0°C has more internal energy than 1.0 kg of ice at 0°C. *(2 marks)*

5 Explain, in terms of internal energy, why a window gets slightly warmer when water vapour condenses on its surface. *(2 marks)*

Exercise B

1 Calculate the energy required to raise the temperature of the following substances by 20°C.
a 1.0 kg of water b 600 g of aluminium c 4.2 μg of lead. *(4 marks)*

2 Describe an experiment that can be used to determine the specific heat capacity of a block of metal using an electrical heater, stating all the measurements that need to be taken. *(7 marks)*

3 This question is about a waterfall. Consider a 1 kg mass of water falling through a vertical drop of 450 m. Assuming all the energy is converted into thermal energy, calculate the difference in temperature between water at the top and bottom of the waterfall. *(3 marks)*

4 A 500 g mass of metal is heated using an electrical heater. The current in the heater and the potential difference across it are 2.0 A and 12 V. After 5.0 minutes the temperature of the metal has risen by 32°C. Calculate the specific heat capacity of the metal and identify the metal from Table 1. *(3 marks)*

5 A 60 W heater is used to heat a substance of mass 30 g. The graph in Figure 5 shows the change in temperature of the substance against time. Use the graph to determine the specific heat capacity of the substance. *(5 marks)*

6 A car of mass 1500 kg has two disc brakes of mass 8.0 kg. The material of the disc has a specific heat capacity of 500 $J\,kg^{-1}\,K^{-1}$. Assuming the kinetic energy of the car is transferred into thermal energy in the discs, calculate the increase in temperature of the brake discs when the car quickly decelerates from 20 $m\,s^{-1}$ to rest. *(3 marks)*

Exercise C

1 Calculate the energy required to change 2.5 kg of silver at its melting point from solid to liquid. *(2 marks)*

2 Describe why the specific latent heat of vaporisation is normally greater than the specific latent heat of fusion for a particular substance. *(1 mark)*

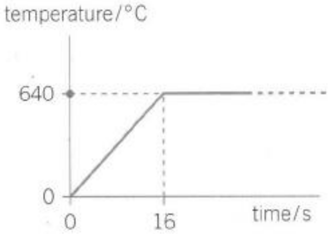
3 Calculate the energy transferred to the surroundings when 50 g of aluminium changes phase from liquid to solid. *(2 marks)*

4 A 24 W electrical heater is used to melt solid water already at its melting point. If the heater is left running for 20 minutes, calculate the mass of ice melted in that time. *(3 marks)*

5 The temperature–time graph in Figure 5 was obtained by heating a small piece of metal of mass 60 g. The specific heat capacity of the metal is 904 $J\,kg^{-1}\,K^{-1}$ and the specific latent heat of fusion is 398 $kJ\,kg^{1}$.
Calculate:

a the rate of energy transfer to the metal from the heater *(3 marks)*

b the energy required to melt the metal. *(2 marks)*



▲ Figure 5 *A graph of temperature against time obtained when heating a small piece of metal*

6 A small lead bullet of mass 8.0 g travels at 400 $m\,s^{-1}$. The bullet strikes a concrete wall and melts on impact. Assuming the bullet is at 40°C on impact and that all the kinetic energy of the bullet is used to heat and then melt the bullet, calculate the temperature of the molten lead left on the wall. The specific heat capacity of lead is 129 $J\,kg^{-1}\,K^{-1}$ (assume this is unchanged for molten lead). *(6 marks)*

Exercise D

1 Calculate the number of elementary entitles (atoms or molecules) in 3.0 mol of a substance. *(2 marks)*

2 Suggest why one mole of silicon has a different mass from one mole of aluminium. *(2 marks)*

3 A molecule of mass 5.3×10^{-26} kg travelling at 500 $m\,s^{-1}$ collides with a container wall. It collides at right angles to the wall. Calculate the change in the momentum of this molecule. *(2 marks)*

4 Calculate the number of moles there are in a substance containing:

a 2.0×10^{24} molecules

b 1.5×10^{17} atoms

c 2.0×10^{24} molecules. *(3 marks)*

5 a The molar mass of copper is 64 $g\,mol^{-1}$ calculate the number of atoms in copper of mass 1.0 kg. *(2 marks)*

b The molar mass of uranium is 235 $g\,mol^{-1}$. Calculate the mass of a single atom of uranium. *(2 marks)*

6 The density of lead is 11340 $kg\,m^{-3}$. Each lead atom has a mass of 3.46×10^{-25} kg. Calculate the number of moles of lead in a lead block with a volume of 0.20 m^3. *(4 marks)*

Exercise E

1 A sealed container contains 60 moles of gas at temperature of 250 K and a pressure of 60 000 Pa. Calculate the volume of the container. *(2 marks)*

2 State the effect on the pressure of a fixed mass of gas at constant temperature if the volume of gas is:
a doubled;
b reduced to a third of its original value. *(2 marks)*

3 A fixed mass and volume of gas initially at a temperature of 20°C and pressure of 300 kPa is heated to 100°C. Calculate the change in pressure. *(4 marks)*

4 Using the values from Figure 4, plot a graph of p against $\frac{1}{V}$.
Use this graph to determine the number of moles of gas used in the experiment. The temperature of the gas during the experiment was a constant 20 °C. *(4 marks)*

5 Standard conditions for temperature and pressure (STP) are 0°C and 100 kPa. Calculate the volume occupied by 1 mol of air at STP. *(3 marks)*

6 Calculate the number of particles in a gas sample if, when the sample is in a sealed container of volume 0.25 m^3 at a temperature of 15°C, the pressure inside the container is 50 kPa. *(4 marks)*

7 Use the equation of state of an ideal gas to estimate the amount of air in your lungs. *(4 marks)*

Exercise F

1 Calculate the mean speed $\bar{c}$, mean squared speed $\overline{c^2}$, and r.m.s. speed $c_{r.m.s.}$ of a small group of atoms with the following velocities: +100 m s^{-1}, −200 m s^{-1}, +150 m s^{-1}, −50 m s^{-1}. *(3 marks)*

2 Describe how the speeds of the particles in a gas change as the temperature of the gas increases. *(2 marks)*

3 A gas cylinder contains nitrogen at a pressure of 800 kPa. The cylinder contains 4.0×10^{25} molecules and each molecule has a mass of 4.7×10^{-26} kg. The r.m.s. speed of the molecules is 450 m s^{-1}. Calculate the volume of the cylinder. *(3 marks)*

4 Calculate the pressure inside the cylinder in question 3 if the r.m.s. speed of the molecules inside the cylinder increases to 600 m s^{-1}. *(3 marks)*

5 One mole of oxygen has a mass of 0.032 kg. An oxygen cylinder has a volume of 0.020 m^3 at a pressure of 140 kPa. It contains 2.0 moles of oxygen. Calculate:
a the number of molecules inside the cylinder
b the mass of each molecule
c the r.m.s. speed of the oxygen molecules in the cylinder. *(6 marks)*
