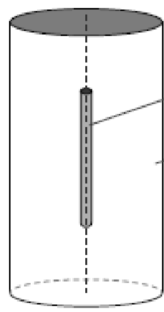
HL Paper 2

The first scientists to identify alpha particles by a direct method were Rutherford and Royds. They knew that radium-226 ($^{226}_{86}\mathrm{Ra}$) decays by alpha emission to form a nuclide known as radon (Rn).

At the start of the experiment, Rutherford and Royds put 6.2 x 10^{-4} mol of pure radium-226 in a small closed cylinder A. Cylinder A is fixed in the centre of a larger closed cylinder B.



The experiment lasted for 6 days. The decay constant of radium-226 is 1.4 x 10^{-11} s^{-1}.

At the start of the experiment, all the air was removed from cylinder B. The alpha particles combined with electrons as they moved through the wall of cylinder A to form helium gas in cylinder B.

a. Write down the nuclear equation for this decay. [2]

b.i. Deduce that the activity of the radium-226 is almost constant during the experiment. [2]

b.ii. Show that about 3 x 10^{15} alpha particles are emitted by the radium-226 in 6 days. [3]

c.i. The wall of cylinder A is made from glass. Outline why this glass wall had to be very thin. [1]

c.ii. The experiment was carried out at a temperature of 18 °C. The volume of cylinder B was 1.3 x 10^{-5} m^3 and the volume of cylinder A was negligible. Calculate the pressure of the helium gas that was collected in cylinder B over the 6 day period. Helium is a monatomic gas. [3]

A closed box of fixed volume 0.15 m^3 contains 3.0 mol of an ideal monatomic gas. The temperature of the gas is 290 K.

When the gas is supplied with 0.86 kJ of energy, its temperature increases by 23 K. The specific heat capacity of the gas is 3.1 kJ kg^{-1} K^{-1}.

Determine, in kJ, the total kinetic energy of the particles of the gas.

0.46 mole of an ideal monatomic gas is trapped in a cylinder. The gas has a volume of 21 m^3 and a pressure of 1.4 Pa.

(i) State how the internal energy of an ideal gas differs from that of a real gas.

(ii) Determine, in kelvin, the temperature of the gas in the cylinder.

(iii) The kinetic theory of ideal gases is one example of a scientific model. Identify **two** reasons why scientists find such models useful.

This question is about an ideal gas.

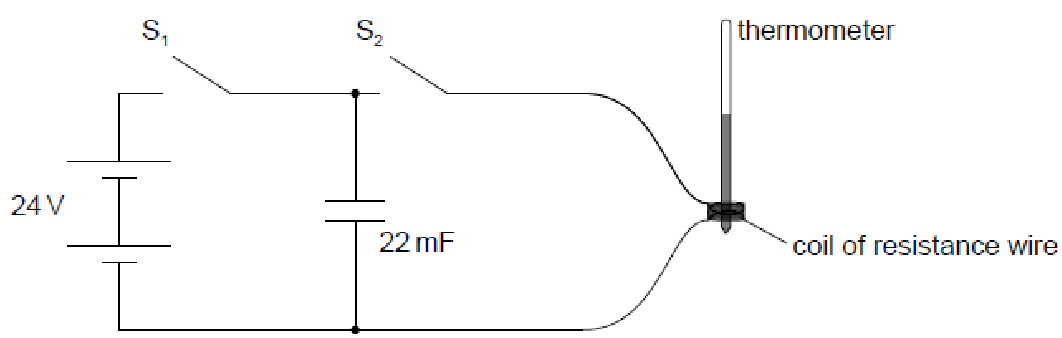
a. Describe how the ideal gas constant *R* is defined. [2]

b. Calculate the temperature of 0.100 mol of an ideal gas kept in a cylinder of volume $1.40\times10^{-3}\,m^3$ at a pressure of 2.32×10^5 Pa. [1]

c. The gas in (b) is kept in the cylinder by a freely moving piston. The gas is now heated at constant pressure until the volume occupied by the gas is $3.60\times10^{-3}\,m^3$. The increase in internal energy of the gas is 760 J. Determine the thermal energy given to the gas. [2]

d. After heating, the gas is compressed rapidly to its original volume in (b). Outline why this compression approximates to an adiabatic change of state of the gas. [2]

The electrical circuit shown is used to investigate the temperature change in a wire that is wrapped around a mercury-in-glass thermometer.



A power supply of emf (electromotive force) 24 V and of negligible internal resistance is connected to a capacitor and to a coil of resistance wire using an arrangement of two switches. Switch S_1 is closed and, a few seconds later, opened. Then switch S_2 is closed.

a. The capacitance of the capacitor is 22 mF. Calculate the energy stored in the capacitor when it is fully charged. [1]

b. The resistance of the wire is 8.0 Ω. Determine the time taken for the capacitor to discharge through the resistance wire. Assume that the capacitor is completely discharged when the potential difference across it has fallen to 0.24 V. [3]

c.i. The mass of the resistance wire is 0.61 g and its observed temperature rise is 28 K. Estimate the specific heat capacity of the wire. Include an appropriate unit for your answer. [2]

c.ii. Suggest **one** other energy loss in the experiment and the effect it will have on the value for the specific heat capacity of the wire. [2]

This question is about internal energy.

Humans generate internal energy when moving, while their core temperature remains approximately constant.

Distinguish between the concepts of internal energy and temperature.

Part 2 Properties of a gas

a. With respect to a gas, explain the meaning of the terms thermal energy and internal energy. [2]

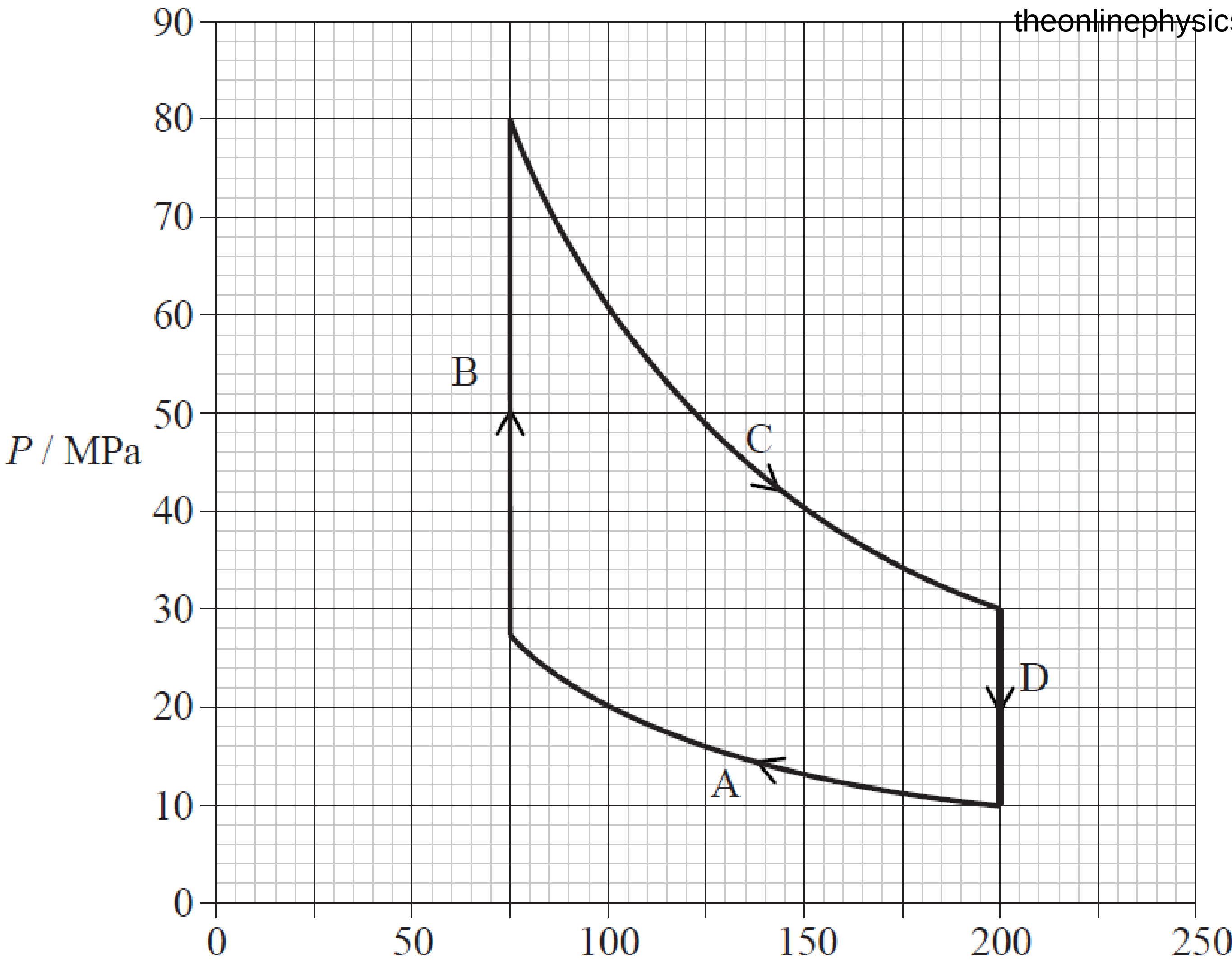
Thermal energy: . . . .

. . . .

Internal energy: . . . .

. . . .

b. The graph shows how the pressure *P* of a sample of a fixed mass of an ideal gas varies with volume *V*. The gas is taken through a cycle **ABCD.** [10]



V / 10^{-6} m^3

(i) Estimate the net work done during the cycle.

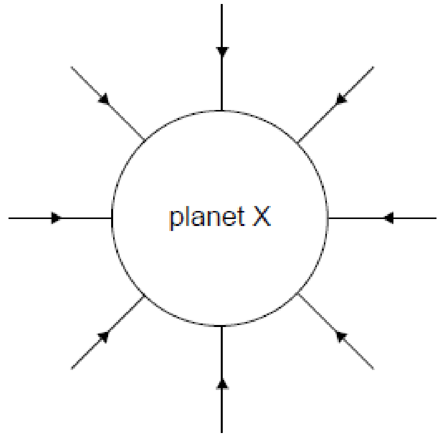
(ii) Explain whether the net work is done on the gas or by the gas.

(iii) Deduce, using the data from the graph, that the change **C** is isothermal.

(iv) Isothermal change **A** occurs at a temperature of 450 K. Calculate the temperature at which isothermal change **C** occurs.

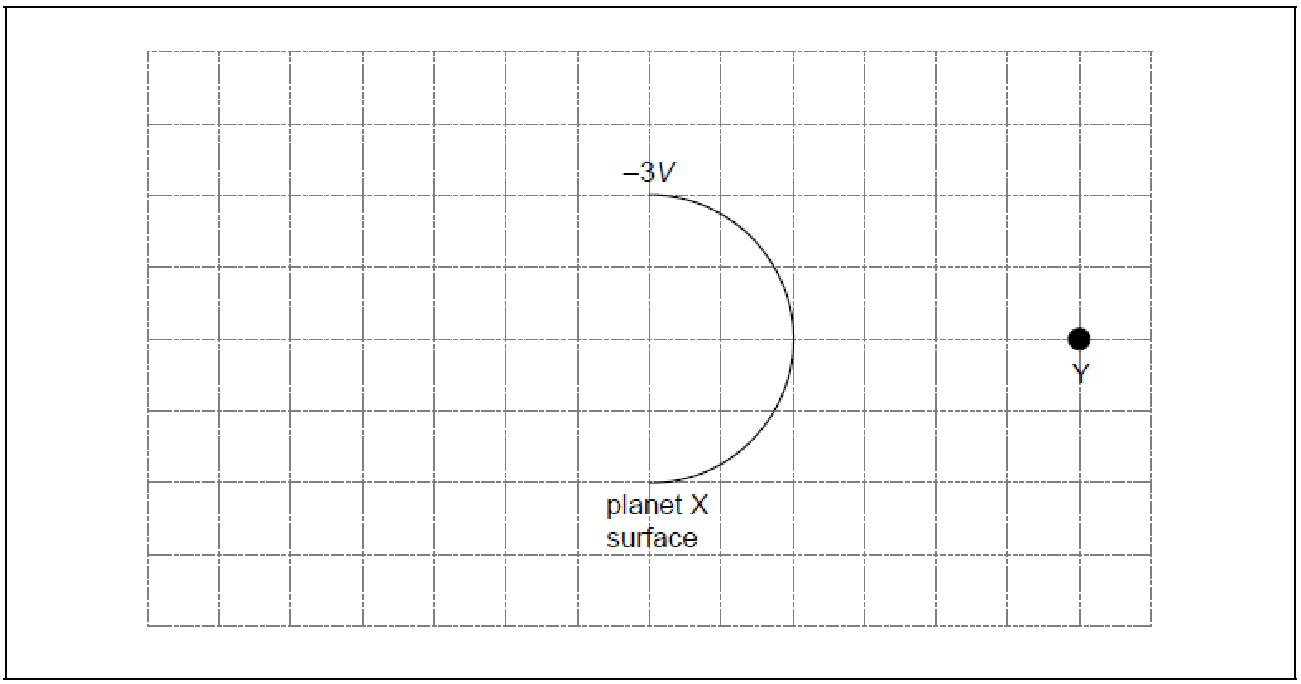
(v) Describe the changes **B** and **D**.

The diagram shows the gravitational field lines of planet X.



a. Outline how this diagram shows that the gravitational field strength of planet X decreases with distance from the surface. [1]

b. The diagram shows part of the surface of planet X. The gravitational potential at the surface of planet X is $-3V$ and the gravitational potential at point Y is $-V$. [2]



Sketch on the grid the equipotential surface corresponding to a gravitational potential of $-2V$.

c. A meteorite, very far from planet X begins to fall to the surface with a negligibly small initial speed. The mass of planet X is 3.1×10^{21} kg and its radius is 1.2×10^{6} m. The planet has no atmosphere. Calculate the speed at which the meteorite will hit the surface. [3]

d. At the instant of impact the meteorite which is made of ice has a temperature of 0 °C. Assume that all the kinetic energy at impact gets transferred into internal energy in the meteorite. Calculate the percentage of the meteorite's mass that melts. The specific latent heat of fusion of ice is 3.3×10^{5} J kg^{-1}. [2]