1 **(a)** The molar mass of hydrogen gas is $2.02 \times 10^{-3}\,kg\,mol^{-1}$. Calculate the mass of a hydrogen molecule.

mass = ... kg **[2]**

(b) The temperature of the Earth's upper atmosphere is about 1100 K. Show that at this temperature the mean kinetic energy of an air molecule is about 2×10^{-20} J.

[2]

(c) Show that the speed of a helium atom of mass 6.6×10^{-27} kg at a temperature of 1100 K is about $2.5\,km\,s^{-1}$.

[2]

(d) The *escape velocity* from the Earth is $11\,km\,s^{-1}$. The escape velocity is the minimum vertical velocity a particle must have in order to escape from the Earth's gravitational field. Explain why helium atoms still escape from the Earth's atmosphere.

....

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.... **[2]**

[Total: 8]

2 **(a)** **(i)** Define the *kilowatt-hour*.

....

.... **[1]**

(ii) A domestic refrigerator works at a mean power of 70W. Calculate the cost of running this refrigerator for one week at a cost of 12p per kWh.

cost = £ .... **[2]**

(b) A large jug containing 2.0kg of milk is placed in a refrigerator. The milk cools from 18°C to 3.0°C over a time period of 100 minutes. The specific heat capacity of milk is 3800 $J\,kg^{-1}\,K^{-1}$.

Calculate

(i) the thermal energy removed from the milk as it cools from 18°C to 3°C

energy removed = ... J **[2]**

(ii) the rate at which thermal energy is removed from the milk.

rate = ... $J\,s^{-1}$ **[1]**

(c) Another container full of milk is placed in a freezer and cooled from 18 °C to –18 °C.

Assume that thermal energy is removed at a constant rate and that the freezing-point of milk is 0 °C. The specific heat capacity of milk below 0 °C is significantly less than its value above 0 °C.

On Fig. 3.1 sketch a graph to show the variation with time of the temperature of the milk over the range 18 °C to –18 °C. Numbers are not required on the time axis.

Fig. 3.1 **[3]**

[Total: 9]

3 **(a)** A student investigates Brownian motion by observing through a microscope smoke particles suspended in air.

(i) Describe the behaviour of the smoke particles as observed by the student.

In your answer, you should use appropriate technical terms spelled correctly.

....

.... **[1]**

(ii) State how the observations lead to conclusions about the nature and properties of the molecules of a gas.

....

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.... **[3]**

(b) The molar masses of hydrogen and oxygen are 0.0020 kg mol^{-1} and 0.032 kg mol^{-1} respectively. The mean speed of hydrogen molecules at room temperature is 1800 m s^{-1}.

Calculate the mean speed of oxygen molecules at the same temperature.

mean speed = ... m s^{-1} **[3]**

[Total: 7]

4 **(a)** **(i)** State Boyle's law.

....

.... **[2]**

(ii) For a gas which obeys Boyle's law, sketch

1 on Fig. 6.1 a graph of pressure p against volume V

2 on Fig. 6.2 a graph of p against $1/V$. **[3]**

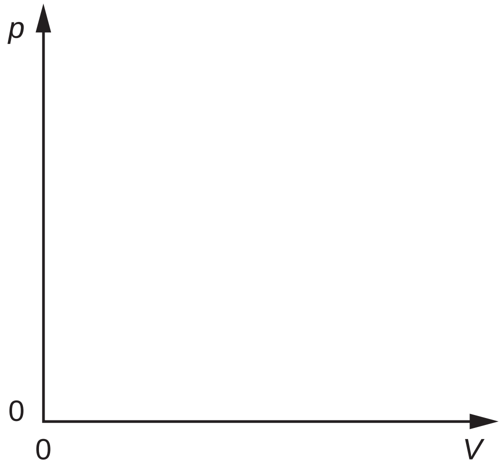

Fig. 6.1

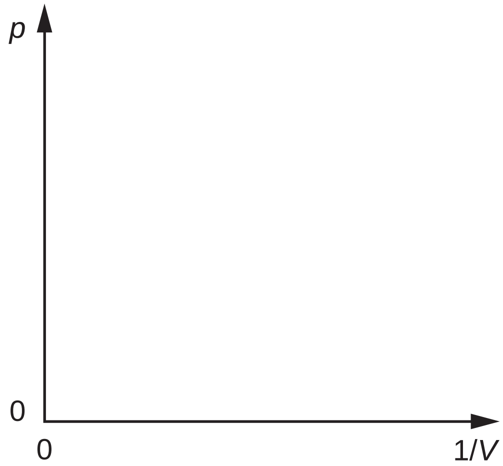

Fig. 6.2

(b) A cylinder of fixed volume 0.040 m^3 is filled with nitrogen gas at a pressure of 5.0×10^5 Pa and temperature 15 °C. The molar mass of nitrogen is 0.028 kg mol^{-1}.

(i) Calculate the number of moles of nitrogen in the cylinder.

number of moles = ... **[2]**

(ii) After a period of 100 days the pressure has fallen to 4.5×10^5 Pa, at the same temperature, because of leakage. Calculate the mass of nitrogen that has escaped.

mass = ... kg **[3]**

[Total: 10]

5 **(a)** The table shows the specific heat capacities c of alcohol and water.

	c / J kg^{-1} K^{-1}
alcohol	2460
water	4180

(i) An alcohol thermometer is placed in 80 g of water at 20 °C. The mass of alcohol in the thermometer is 0.050 g. The water is then heated from 20 °C to 60 °C.

Calculate the ratio

$$\frac{\text{energy required to warm the water from 20 °C to 60 °C}}{\text{energy required to warm the alcohol from 20 °C to 60 °C}}.$$

ratio = ... **[2]**

(ii) State and explain a situation in which the very high value of specific heat capacity for water is useful.

....

....

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....

.... **[2]**

(b) Describe an electrical experiment to determine the specific heat capacity *c* of a liquid.

Include in your answer:

- a labelled diagram of the arrangement
- a list of the measurements to be taken
- an explanation of how the value of *c* would be determined from your results
- possible sources of uncertainty in your measurements and how these could be reduced.

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[Total: 12]