1)

The temperature of a hot liquid in a container falls at a rate of 2 K per minute just before it begins to solidify. The temperature then remains steady for 20 minutes by which time all the liquid has all solidified.

What is the quantity $\frac{\text{Specific heat capacity of the liquid}}{\text{Specific latent heat of fusion}}$ ?

**A** $\frac{1}{40}\text{K}^{-1}$ ☐

**B** $\frac{1}{10}\text{K}^{-1}$ ☐

**C** 10 $\text{K}^{-1}$ ☐

**D** 40 $\text{K}^{-1}$ ☐

**(Total 1 mark)**

2)

A tea urn has two elements used to heat the water; a slow one used for heating the full urn over a long period of time (taking $t_1$ minutes) and a fast one used for heating the full urn quickly (taking $t_2$ minutes). If both elements are used at the same time, how long will it now take to heat the full urn?

A. $t_1 + t_2$ mins. B. $\frac{t_1}{t_2}$ mins. C. $\sqrt{(t_1^2 + t_2^2)}$ mins. D. $\frac{t_1 t_2}{t_1+t_2}$ mins.

3)

What must be the speed of a lead bullet if it melts when it strikes a steel slab? The initial temperature of the bullet is 27 °C. The melting point of lead is 327 °C, its latent heat of melting is $2.1 \times 10^4$ J kg$^{-1}$ and its specific heat capacity is 126 J kg$^{-1}$ °C$^{-1}$. Assume that all of the kinetic energy is converted to heat energy in the bullet.

**(4 marks)**

4)

(a) An electric kettle is filled with 1.50 kg of water at 20°C.The power of the kettle's element is 2.1 kW. After switching on, the water reaches boiling point in 240 s. Calculate a value for the specific heat capacity of water. Assume that all the energy produced by the element is transferred to the water.

(b) The thermostat of the kettle jams and the water continues to boil. After 800 s only one-half of the water remains, the rest having turned to vapour. Calculate a value for the specific latent heat of vaporisation of water at 100°C.

(c) The vapour in (b) has a density 1/1600 of that of boiling water. Estimate the ratio of the mean separation of water molecules at 100°C in the vapour to that in the liquid.

(10 marks)

5)

This question looks at some practical consequences of the evaporation of liquids.

Placing a liquid in a vacuum (e.g. a leak from a space vehicle) forces it to evaporate and can lead to rapid cooling.

a. A water droplet at 10 °C escapes into space and begins to evaporate. Find its temperature when it has lost 1% of its mass. (To heat 1 kg of water by 1 °C requires 4.2 kJ of energy; to evaporate 1 kg of water requires 2.26 MJ of energy)

b. You come out of warm water after bathing. Use your result in (a) above to explain why you feel cold even if it is a very warm day.

c. Why is the result more marked if you are subjected to a draught?

d. Why does applying a volatile liquid, such as ethanol, to your hand feel particularly cold?

**5 marks**

6)

This question refers to a novel form of environmentally friendly home heating.

It is proposed that houses having an outdoor swimming pool could be heated in winter by extracting the thermal energy of the pool, which has been accumulated by natural solar heating in the summer months.

For the purposes of this problem we will assume that such a pool has dimensions 8 m x 20 m and a uniform depth of 2 m, and that a typical, well insulated house requires an average of 5 kW of heating power for the 200 days of colder weather each year.

a) What is the mass of the water in the pool?

b) How much energy must be removed from the pool for its temperature to decrease by 1 K?

c) How much energy is required by the house during the period of colder weather?

d) Hence, calculate the fall in temperature of the pool over the winter period, if it were the only source of heating for the house, and state one assumption you have made.

e) Suggest a reason why the temperature of the pool cannot be reduced indefinitely. Therefore, what is the lowest reasonable temperature of the pool at the end of the period of colder weather?

f) Hence, what does the maximum temperature of the pool need to be at the end of the period of warmer weather, if this system is to be viable?

g) Comment of the feasibility of this approach to domestic heating in the British climate.

Useful data:

| | |
|---|---|
| Density of water | $1\,000$ kg m$^{-3}$ |
| Specific heat capacity of water | $4\,200$ J kg$^{-1}$ K$^{-1}$ |

**10 marks**

7)

An astronaut undertaking a spacewalk faces many dangers, one of which is overheating. The glare of the sun on one side of the suit, with the intense cold of space on the other side of the suit, can produce extreme temperature differences, whilst the heat generated by the astronaut inside the suit is at least as much of a problem.

We can estimate how long he could survive if his internally generated heat energy is not removed. For a 75 kg astronaut generating 240 W through his exertions, his temperature will rise rapidly and he will be unable to function when his core temperature increases to about 40.5 °C from the normal 38.5 °C.

We can assume that his body is mainly water, which has a specific heat capacity, $c$, of 4200 J kg$^{-1}$ °C$^{-1}$. The energy supplied, $\Delta E$, is related to the temperature rise, $\Delta\theta$, and mass, $\Delta m$, through

$$\Delta E = mc\Delta\theta$$

a) Calculate the amount of energy required to raise his body temperature by 1 °C.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________ [2]

b) What is the rate of increase of his body temperature due to his exertions?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________ [2]

c) How long will it take the astronaut to become unable to function due to his temperature rise?

______________________________________________________________________

______________________________________________________________________ [1]

/5

8)

When liquid nitrogen at a temperature of 77 kelvin or -196 $^{o}$C is poured into a beaker, it is observed to boil continuously as heat enters it from the surroundings. When stored in a full 25 litre Dewar flask (an insulated steel container similar to a thermos flask), it takes 100 days for all of the liquid nitrogen to boil away. The rate at which heat enters (i.e. power entering) the Dewar flask is very low and we can estimate the value using the results of the following experiment.


**Figure 3. Liquid nitrogen Dewar**


**Figure 4. Electrical heater suspended in liquid nitrogen**

A beaker of liquid nitrogen is placed on an electronic balance and readings of the mass are taken every twenty seconds. A small electrical heater is suspended in the liquid, and the experiment is carried out twice, once with the heater turned off and then repeated with the heater connected to the electrical supply. A graph is plotted of the two sets of results and the lines of best fit are obtained, along with the equations. The graph is shown below.

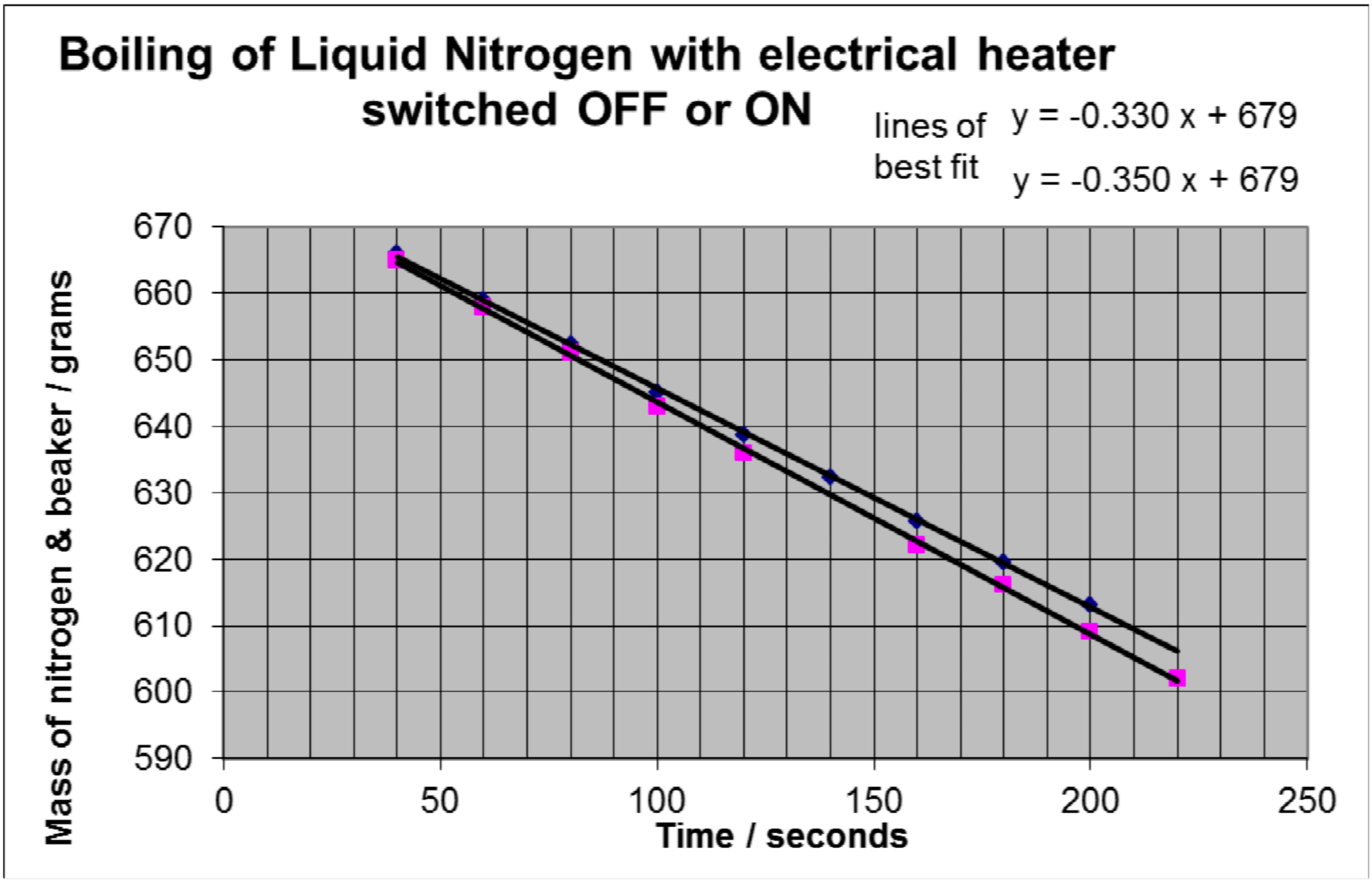
a) Calculate the rate of loss of liquid nitrogen in grams per second, for each of the two cases, using the data from the graph. The equations for the lines of best fit are given. **(2)**

b) The heater supply is V=3.9 volts, I=1.2 amps. Calculate the number of joules per second supplied by the heater. **(1)**

c) Calculate the energy from the heater required to boil away one gram of liquid nitrogen. **(2)**

d) Calculate the heat power from the room entering the beaker of nitrogen. **(2)**

e) Calculate the average power that must enter the full 25 litre Dewar to boil away the nitrogen in 100 days. Density of liquid nitrogen is 810 kg $m^{-3}$ (1 $m^3$ = 1000 litres). **(5)**




**(12 marks)**

9)

An explorer tests her gas fuelled cooking stove before setting off on an expedition. She has a pot which has a square base of side 10 cm and height 15 cm. Starting from 20 °C, how much energy is required to heat the water in a totally full pot to boiling point? (You may assume the specific heat capacity of water is $4.2\ \mathrm{kJ\,kg^{-1}\,K^{-1}}$ and the density of water is $1\ \mathrm{g\,cm^{-3}}$. You may also neglect the specific heat capacity of the pot.) [4]

b)

The explorer now goes up Mount Everest. She discovers that the boiling point of water decreases by 1 °C every 300 m. What physical effect causes this reduction in boiling point? [1]

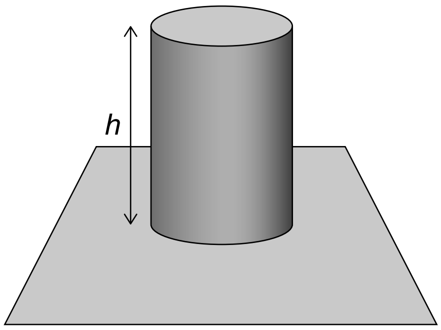
c)

When she reaches 6000 m she uses her stove to make a cup of tea. Her mug only requires 100 g of water. How much energy will it take to boil the water and make the cup of tea (assuming it is 10 °C in her tent at 6000 m)? [2]

d)

She discovers there is a problem with her stove and it now only produces 50 % of the power it did at sea level. If a full pot took 15 minutes to reach boiling point at sea level, how long will it take to boil the water for the cup of tea? [3]

**10.** A solid cylinder of height $h$ and density $\rho$ rests on a flat surface.




(a) Show that the pressure $p_C$ exerted by the cylinder on the surface is given by $p_C = \rho gh$. [2]

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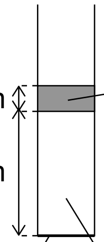
(b) A tube of constant circular cross-section, sealed at one end, contains an ideal gas trapped by a cylinder of mercury of length 0.035 m. The whole arrangement is in the Earth's atmosphere. The density of mercury is $1.36 \times 10^4\,\text{kg m}^{-3}$.




When the mercury is above the gas column the length of the gas column is 0.190 m.

(i) Show that $(p_o + p_m) \times 0.190 = \dfrac{nRT}{A}$ where

$p_o$ = atmospheric pressure
$p_m$ = pressure due to the mercury column
$T$ = temperature of the trapped gas
$n$ = number of moles of the trapped gas
$A$ = cross-sectional area of the tube. [2]

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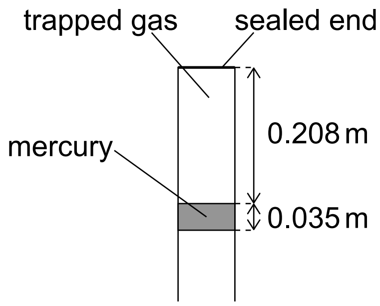
**(This question continues on the following page)**

**(Question 10 continued)**

(ii) The tube is slowly rotated until the gas column is above the mercury.

**diagram not to scale**




The length of the gas column is now 0.208 m. The temperature of the trapped gas does not change during the process.

Determine the atmospheric pressure. Give a suitable unit for your answer. [4]

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(iii) Outline why the gas particles in the tube hit the mercury surface less often after the tube has been rotated. [1]

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**3** **(a)** State what is meant by *specific latent heat*.

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**(b)** A student determines the specific latent heat of vaporisation of a liquid using the apparatus illustrated in Fig. 3.1.

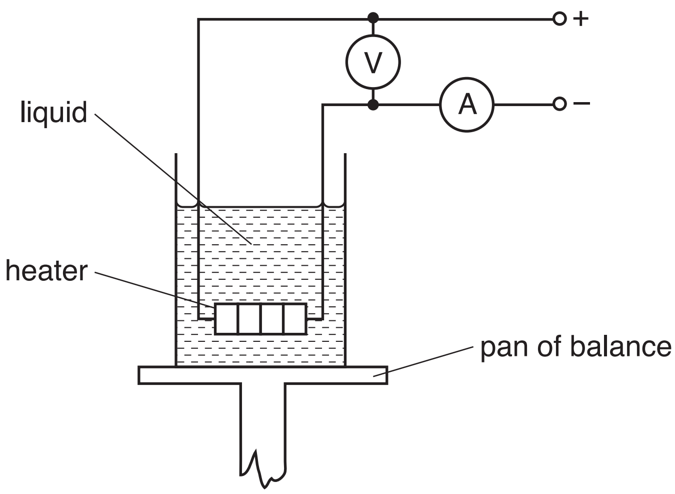


**Fig. 3.1**

The heater is switched on. When the liquid is boiling at a constant rate, the balance reading is noted at 2.0 minute intervals.

After 10 minutes, the current in the heater is reduced and the balance readings are taken for a further 12 minutes.

The readings of the ammeter and of the voltmeter are given in Fig. 3.2.

| | ammeter reading / A | voltmeter reading / V |
|---|---|---|
| from time 0 to time 10 minutes<br>after time 10 minutes | 1.2<br>1.0 | 230<br>190 |

**Fig. 3.2**

The variation with time of the balance reading is shown in Fig. 3.3.

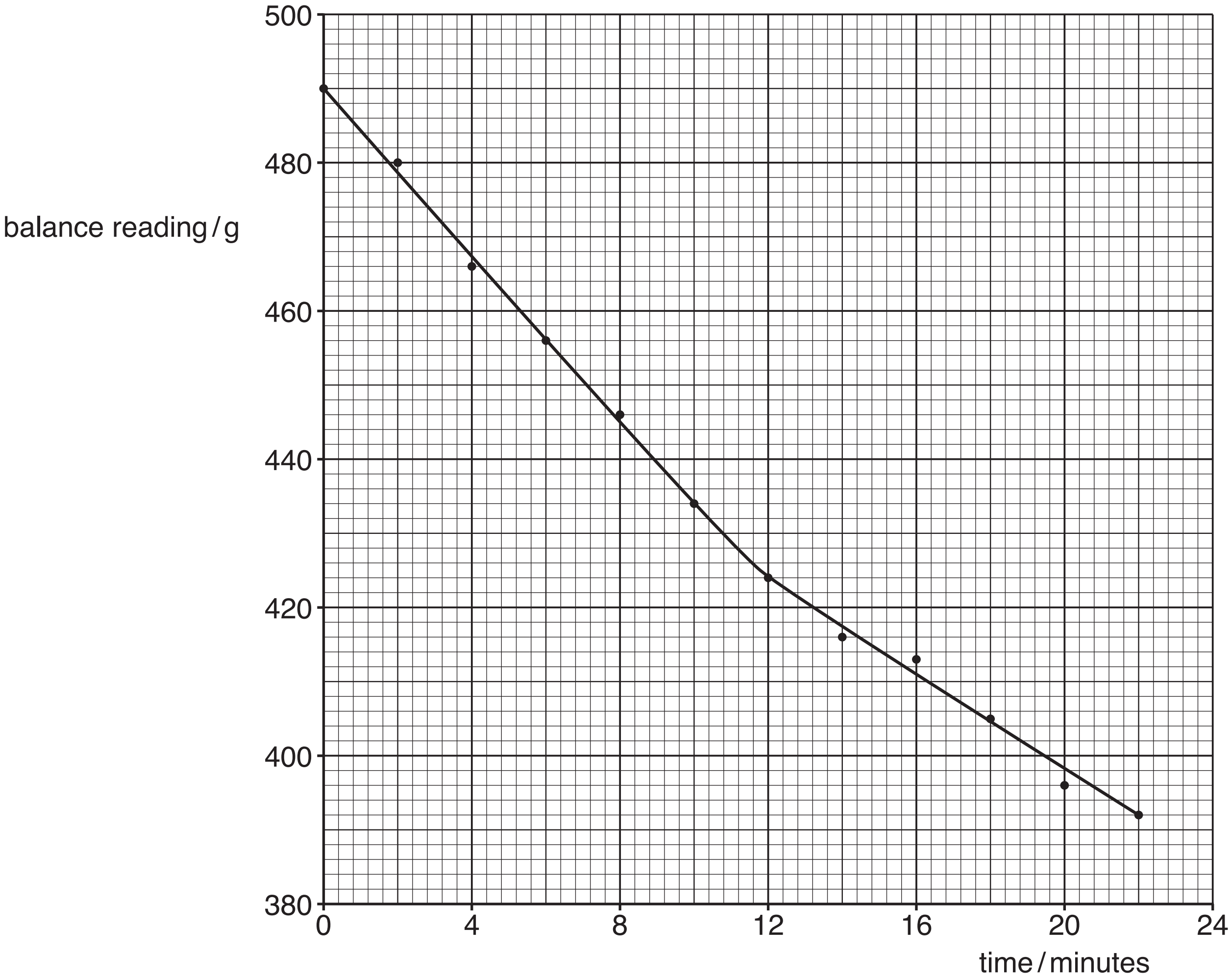


**Fig. 3.3**

**(i)** From time 0 to time 10.0 minutes, the mass of liquid evaporated is 56 g.

Use Fig. 3.3 to determine the mass of liquid evaporated from time 12.0 minutes to time 22.0 minutes.

mass = ...................................................... g [1]

**(ii)** Explain why, although the power of the heater is changed, the rate of loss of thermal energy to the surroundings may be assumed to be constant.

...................................................................................................................................

................................................................................................................................... [1]

**(iii)** Determine a value for the specific latent heat of vaporisation *L* of the liquid.

*L* = ................................................ $J g^{-1}$ [4]

**(iv)** Calculate the rate at which thermal energy is transferred to the surroundings.

rate = .................................................... W [2]

[Total: 10]