Where necessary in this set, use
specific heat capacity of water = 4.19 kJ kg^{-1} K^{-1}
specific latent heat of vaporisation of water = 2.26 MJ kg^{-1}
specific latent heat of fusion of ice = 334 kJ kg^{-1}

1 If a cup of coffee loses 10 kJ of heat while its temperature drops 20 degrees on the Celsius scale, what is its heat capacity?

2 If the heat capacity of an electric kettle is 400 J K^{-1}, how much heat does it absorb as its temperature rises from 20°C to 95°C while heating some water for a cup of tea?

3 In a family room with an initial temperature of 10°C a wood fire is being started on a steel grate of heat capacity 1.50 kJ K^{-1}. What is the temperature of the grate by the time it has absorbed 540 kJ of heat from the fire?

4 How much heat is absorbed by a 2.8 kg brick sitting in the sun while its temperature rises from 18°C to 28°C? The specific heat capacity of a brick is 7.5×10^2 J kg^{-1} K^{-1}.

5 In an experiment to determine a value for the specific heat capacity of water two students found that the temperature of 0.15 kg of water rose from 17°C to 35°C as the water absorbed 11 kJ of heat energy. What value did they obtain?

6 If you had a suitable source which could provide you with 5 MJ of heat energy, as well as an unlimited supply of water (at room temperature), teabags, cups, teaspoons, etc., how many cups of tea could you make? Give your answer as an order of magnitude.

7 A solar flat plate collector for a domestic hot water system on a Sydney home has a collector area of 3.2 m^2. At one stage during the day when the collector happens to be at right angles to the Sun's rays, water is moving through it at the rate of 12 g s^{-1}. Radiant energy is falling on the collector at the rate of 210 W m^{-2}, and 82 per cent of the incident energy is absorbed by the water. By how much does the temperature of the water rise as it passes through the collector?

8 In the continuous flow calorimeter shown in Figure 49.1 with the 200 W electric heater turned on, water flows through at the rate of 0.119 kg min^{-1}. When the two thermometer readings become steady, the various parts of the apparatus will have attained different but steady temperatures, and so no part of the apparatus is being heated up. If the inlet temperature is 16°C, what is the outlet temperature?

9 As a cloud cools from 24°C to 4°C, 72 kg of rain is formed. How much heat is released into the atmosphere during this process?

10 At what minimum speed would a steel bullet at a temperature of 21°C have to be travelling in order to reach a temperature of 1000°C on hitting a sheet of armourplate steel? Assume the bullet retains 70 per cent of the heat energy it generates. Specific heat capacity of steel = 4.8×10^2 J kg^{-1} K^{-1}.

11 On his honeymoon Joule measured the temperature at the bottom of a waterfall to see if it was higher than the temperature at the top.
(*a*) What increase in temperature would you expect at the Tully Falls near Ravenshoe in Queensland? They are 270 m high.
(*b*) In fact would you expect the temperature rise to be greater or less than your answer to (*a*)? Give a reasoned response.

12 The specific heat capacity of copper is 3.8×10^2 J kg^{-1} K^{-1}. If a copper calorimeter has a mass of 55 g, determine its
(*a*) heat capacity;
(*b*) water equivalent, i.e. the mass of water, which has the same heat capacity as the calorimeter.

13 54 g of water at 60°C is poured into a calorimeter which has a heat capacity of 25 J K^{-1} (or water equivalent 6.0 g) and which contains 120 g of water at 10°C. If the heat exchange with the surroundings is negligible, what is the highest temperature reached by the mixture?

14 A calorimeter of heat capacity 33 J K^{-1} (or water equivalent 8.0 g) contains 123.4 g of water at 16.2°C. To this is added some water at 37.3°C, and, after stirring, the highest temperature reached in the calorimeter is 21.0°C.

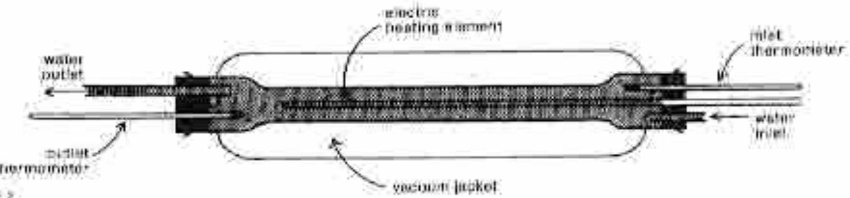

Fig. 49.1

(*a*) Assuming the heat losses to the surroundings are negligible, determine the mass of water added.
(*b*) Actually there would have been some heat exchange with the surroundings. Would the actual mass of water added be greater or less than your answer to (*a*)?

15 The single outlet connected to both taps over a kitchen sink is supplied with cold water at 8.0°C and hot water at 64°C. The cold water tap is giving a flow of 8.0 litre min^{-1} and the hot water tap is then adjusted to give a total flow rate of 14.0 litre min^{-1} through the outlet. What is the resulting temperature of the warm water?

16 In an experiment to find the specific heat capacity of iron, 30.0 g of iron tacks at 100°C are dropped into a calorimeter of heat capacity 25 J K^{-1} (or water equivalent 6.0 g) containing 54.0 g of water at 13.2°C, and the final temperature is found to be 18.0°C. What value does this give for the specific heat capacity of iron? Assume heat losses to the surroundings are insignificant.

17 You pour yourself a beer (or perhaps an orange drink) from the refrigerator into a glass which is at room temperature. Making sensible estimates, determine by how much the temperature of your drink will rise as a result of using an unchilled glass. Give your answer as an order of magnitude. Specific heat capacity of glass = 8×10^2 J kg^{-1} K^{-1}.

18 If 4.2×10^3 J of heat energy are required to vaporise 5.0 g of ethanol at its boiling point, what is the specific latent heat of vaporisation of ethanol?

19 A 2100 W electric kettle containing 1.00 litre (i.e. 1.00 kg) of water has just come to the boil.
(*a*) How much energy is required to boil all the water away?
(*b*) How long (to the nearest minute) will it take for the kettle to boil dry?

20 Two adjacent units at a ski resort are identical apart from the fact that the owner of one has installed insulation in the ceiling of his unit. Just 4 h after the snow stops falling, the 80 m^2 roof of the insulated unit has 10 cm of snow on it as the last of the snow melts on the roof of the other unit.
(*a*) How much heat has been wasted by the owner of the uninsulated unit? Take the density of snow as 94 kg m^{-3}.
(*b*) If heat energy costs 0.65 cent MJ^{-1}, what approximate cost saving for the three month skiing period results from insulating the roof? Give your answer to the nearest $10.

21 A cross-country skier descends a 25° slope at a constant speed of 12 m s^{-1}. If all the work done by friction on the lower side of her skis goes into producing heat, what mass of snow does she melt in the 50 s she is descending the slope? Her total mass including skis and pack is 80 kg.

22 Liquid in a vacuum flask is boiled steadily by passing an electric current through a coil of wire immersed in the liquid. When energy is supplied to the coil at the rate of 806.4 J min^{-1}, liquid is changed into vapour at the rate of 0.34 g min^{-1}, and when energy is supplied at the rate of 302.4 J min^{-1}, liquid is changed into vapour at the rate of 0.12 g min^{-1}. Assuming that the rate of loss of heat from the liquid in the flask to the surroundings is H J min^{-1} in each case, write down two equations connecting L, the specific latent heat of vaporisation of the liquid, and H; hence calculate the value of L.

23 Heat is passed at a uniform rate into a vessel containing 50.0 g of ice at 0°C and the whole of the ice is just melted in 10.0 min.
(*a*) Neglecting the heat gained by the vessel and any heat losses to the surroundings, calculate
(*i*) the energy being supplied per minute;
(*ii*) the additional time required to boil all the water away if heat continues to be supplied at the same rate.
(*b*) Actually heat exchanges with the vessel and the surroundings would occur. If these were taken into account, would the real answer to (*a*) (*i*) be higher or lower?

24 An ice-block tray holding 0.25 kg of water at 18°C is placed in the freezing compartment of a refrigerator. If it takes $1\frac{1}{2}$ h to form ice-blocks, at what rate was the refrigerator extracting heat from the water?

25 In Figure 49.2 a hypothetical temperature-time curve has been drawn for 0.80 kg of a solid which is warmed in a well-insulated container by a 100 W heater.

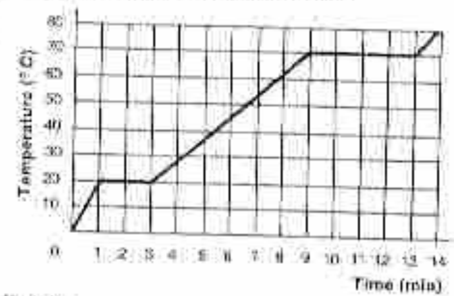

Fig. 49.2

(*a*) What is the melting point of the solid?
(*b*) Which is greater: the substance's specific latent heat of fusion or vaporisation?
(*c*) Which is greatest: the substance's specific heat capacity as a solid, liquid or gas?
(*d*) Determine its specific latent heat of fusion.
(*e*) What is its specific heat capacity as a liquid?

26 A copper calorimeter has a mass of 50 g and contains 85 g of water at 18°C. 6.0 g of dried ice is then added and the contents stirred until all the ice has melted. What is the temperature of the mixture? Specific heat capacity of copper $= 3.8 \times 10^2$ J kg^{-1} K^{-1}.

27 In an espresso coffee machine steam is bubbled through 200 g of coffee-flavoured milk taken from a refrigerator at 2°C. If the final temperature of the coffee is 90°C, what mass of steam condensed? Take the specific heat capacity of the coffee as 4.2 kJ kg^{-1} K^{-1}.

28 A bottle of lemonade is taken from a cupboard (not a refrigerator) at 20°C and 200 g is poured into a glass. Two 25 g ice-blocks are added. The glass has a mass of 120 g and a specific heat capacity of 8.4×10^2 J kg^{-1} K^{-1}. Take the specific heat capacity of lemonade as that of water.
(*a*) If we make the simplification that there is no heat exchange with the surroundings, what would be the temperature of the drink when half the ice has melted?
(*b*) In reality would its temperature be higher or lower than this?

29 A calorimeter which has a mass of 1.00 kg and a specific heat capacity of 8.4×10^2 J kg^{-1} K^{-1} is cooled to 0°C and 1.40 kg of ice at 0°C is placed in it. 1.00 kg of water at 100°C is then poured into the calorimeter. Find the resulting temperature.

30 A lump of copper is heated and placed on a large block of ice at 0°C, into which it sinks until it is three-quarters buried. What was its original temperature? The densities of copper and ice are 8.9×10^3 kg m^{-3} and 9.2×10^2 kg m^{-3}. The specific heat capacity of copper is 3.8×10^2 J kg^{-1} K^{-1}.

31 During dinner the room temperature is 18°C. If your soup has a temperature of 70°C, while your brother's which was served earlier is at 44°C, what is the ratio of the rate at which your soup is cooling down to that at which his is cooling?

32 The temperature of a body falls from 30.0°C to 20.0°C in 5.00 min, the air temperature being 13.0°C. Find the temperature after an equal time interval.

33 A kettle of water previously boiled cools from 62.0°C to 50.0°C in 10.0 min and to 42.0°C in the next 10 min interval.
(*a*) What is the temperature of the surroundings?
(*b*) Calculate the temperature of the kettle after another 10 min interval has elapsed.

34 A copper calorimeter of heat capacity 25 J K^{-1} contains 0.13 kg of glycerol and a 15 W immersion heater. With the room temperature at 20°C the heater is turned on for 4.0 min and then turned off. Temperature readings in the calorimeter are shown in Table 49.1.

Table 49.1

Time (min)	Temperature (°C)
0	20.0
1	22.6
2	25.1
3	27.5
4	30.0
5	29.7
6	29.5
7	29.3
8	29.0

(*a*) Draw a graph of temperature against time for the calorimeter and glycerol.
(*b*) What is the maximum temperature reached?
(*c*) What is the cooling rate (in °C min^{-1}) after the heater is turned off?
(*d*) What is the average "cooling rate" during the first 4 min due to heat loss to the surroundings?
(*e*) What "cooling correction" should be made to the maximum temperature observed to allow for these heat losses?
(*f*) Determine the specific heat capacity of glycerol.

35 In an experiment to determine specific heat capacity of a solid by the method of mixtures, the calorimeter and its contents were initially at 15.0°C, the room temperature being 20.0°C. The heated solid was immersed, and 0.750 min later the maximum temperature was reached at 30.0°C. The temperature then fell at a constant rate of 0.50°C min^{-1}. Find the "cooling correction" to be applied to give the corrected maximum temperature.

36 Table 49.2 shows the specific heat capacity at constant pressure c_p at 273 K and molar mass M for five metals. The column for the molar heat capacity c_m is yet to be filled in.

Table 49.2

Element	c_p (J kg^{-1} K^{-1})	M (kg mol^{-1})	c_m ( )
chromium	464	0.0520	
copper	381	0.0635	
gold	127	0.197	
iron	438	0.0558	
zinc	384	0.0654	

(*a*) What is meant by the *molar heat capacity* of a substance?
(*b*) Express c_m in terms of c_p and M.
(*c*) What is the missing unit for molar heat capacity in Table 49.2?
(*d*) Write down in order the missing molar heat capacities.
(*e*) Use the table to suggest approximately how much heat would be required to raise the temperature of an aluminium saucepan (about 20 mol of aluminium) from about 20°C to 100°C when boiling potatoes.

37 The relative atomic masses of cobalt and tungsten are 58.9 and 184 respectively. If the specific heat capacity of cobalt is 431 J kg^{-1} K^{-1}, find an approximate value for the specific heat capacity of tungsten.

SET 50 THERMODYNAMICS

Topic	*Problems*
Zeroth law of thermodynamics	1–2
Work done by a fluid expanding at constant pressure	3–7
First law of thermodynamics	8–9
Enthalpy	10–13
Molar heat capacities of a gas at constant pressure and constant volume, equipartition of energy	14–18
Relations between pressure, volume and temperature for the adiabatic expansion of a gas	19–21
Applications of the first law to isochoric, isobaric, isothermal and adiabatic processes	22–26
Mixtures of gases involving changes in pressure, volume and temperature but not phase	27
Carnot cycle, Carnot cycle efficiency, second law of thermodynamics	28–31
Entropy, heat engines, steam, internal combustion and diesel engines	32–41
Refrigerators, heat pumps, air conditioners, coefficient of performance	42–46
Third law of thermodynamics	47

Where necessary in this set use
molar gas constant,
$R = 8.31$ J mol^{-1} K^{-1}
Boltzmann constant,
$k = 1.38 \times 10^{-23}$ J molecule^{-1} K^{-1}
Avogadro constant,
$L = 6.02 \times 10^{23}$ mol^{-1}

1 For two bodies to be in thermal equilibrium what physical property must be identical for them?

2 A thermistor (an electronic temperature sensor) is in thermal equilibrium with a large tank of water. The thermistor is transferred quickly to a glass of milk and found to be at the same temperature as the glass of milk. If the glass of milk was then placed in contact with the tank, would there be a net flow of heat from the water to the milk, from the milk to the water, or neither?

3 If as a result of being heated a sample of air is allowed to expand from a volume of 1.20×10^{-3} m^3 to 1.70×10^{-3} m^3 at a constant pressure of 1.1×10^5 Pa, how much work has been done by the expanding air?

4 A sample of ideal gas is contained in a cylinder with a freely moving piston. The gas was initially at a temperature of 300 K, and at the pressure of the air in the laboratory, 10^5 Pa. The volume of the gas was 10^{-4} m^3. The sample of gas was heated, and allowed to expand so that its pressure remained constant until its volume was 2×10^{-4} m^3. This process is represented on the pressure–volume graph in Figure 50.1.

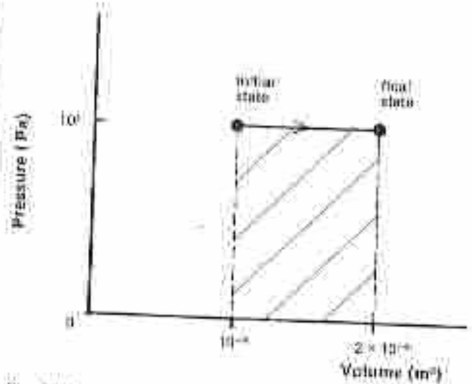

Fig. 50.1

(*a*) What was the final kelvin temperature of the gas?
(*b*) What physical quantity is represented by the area shaded on the graph?
(*c*) How much work was done during the expansion by the gas against the force exerted on the piston by the surrounding air?

5 Taking your average blood pressure as about 13 kPa and making suitable estimates of other quantities, determine as an order of magnitude how much work your heart does in a day.

6 A gas syringe with the outlet closed is held upright and filled with carbon dioxide. The plunger of mass 92 g and diameter 24 mm is fitted and let go. As it moves down the tube a short distance, the plunger does 3.6 mJ of work on the carbon dioxide gas.
(*a*) What pressure is exerted on the carbon dioxide by the weight of the plunger?
(*b*) How far did the plunger drop before coming to rest?
(*c*) In order to answer (*b*) which item of information given in the question was strictly not required?