**1** A liquid flows continuously through a chamber that contains an electric heater. When the steady state is reached, the liquid leaving the chamber is at a higher temperature than the liquid entering the chamber. The difference in temperature is $\Delta t$.

Which of the following will increase $\Delta t$ with no other change?

- **A** Increasing the volume flow rate of the liquid
- **B** Changing the liquid to one with a lower specific heat capacity
- **C** Using a heating element with a higher resistance
- **D** Changing the liquid to one that has a higher density

**(Total 1 mark)**

**2** Two flasks **X** and **Y** are filled with an ideal gas and are connected by a tube of negligible volume compared to that of the flasks. The volume of **X** is twice the volume of **Y**.
**X** is held at a temperature of 150 K and **Y** is held at a temperature of 300 K

What is the ratio $\dfrac{\text{mass of gas in } \mathbf{X}}{\text{mass of gas in } \mathbf{Y}}$ ?

- **A** 0.125
- **B** 0.25
- **C** 4
- **D** 8

$P_y = P_x \quad V_x = 2V_y$

$pV = nRT \Rightarrow n = \frac{pV}{RT}$

$\therefore \frac{n_x}{n_y} = \frac{P_y 2V_y 300R}{150R P_y V_y} = 4$

**(Total 1 mark)**

**3** (a) State **two** assumptions made about the **motion** of the molecules in a gas in the derivation of the kinetic theory of gases equation.

straight lines, random, elastic collisions

**(2)**

(b) Use the kinetic theory of gases to explain why the pressure inside a football increases when the temperature of the air inside it rises. Assume that the volume of the ball remains constant.

particles move faster. → $E_k$ and momentum higher. ∴ impact $\left(\frac{\Delta p}{\Delta t}\right) = F$ is bigger so F exerted on the walls is bigger

**(3)**

(c) The 'laws of football' require the ball to have a circumference between 680 mm and 700 mm. The pressure of the air in the ball is required to be between $0.60 \times 10^5$ Pa and $1.10 \times 10^5$ Pa above atmospheric pressure.

A ball is inflated when the atmospheric pressure is $1.00 \times 10^5$ Pa and the temperature is 17 °C. When inflated the mass of air inside the ball is 11.4 g and the circumference of the ball is 690 mm.

Assume that air behaves as an ideal gas and that the thickness of the material used for the ball is negligible.

Deduce if the inflated ball satisfies the law of football about the pressure.

molar mass of air = 29 g $mol^{-1}$

Vol: $2\pi r = 690 \times 10^{-3}$ m → r = 0.1098

vol = $\frac{4}{3}\pi r^3$ ∴ $V = 5.547 \times 10^{-3}$ $m^3$

Youtube work through

$n = \frac{11.4}{29} = 0.393$

$pV = nRT$

$p = \frac{0.393 \times 8.31 \times 290}{5.55 \times 10^{-3}}$

$p = 1.7 \times 10^5$ Pa

**(6)**

**(Total 11 marks)**

so within limits

see below

range allowed.

$1.6 \to 2.1 \times 10^5$ Pa

More on the football question:
circ between 680 and 700mm
pressure between 0.6x10^5 and 1.1x10^5 Pa above atm

Question:
atm = 1x10^5
temp = 17degrees celcius
mass = 11.4g
circ = 690mm
Molar mass = 29g mol^-1

$Vol = 5.55 \times 10^{-3} m^3$

n = number mole = 0.393

Find P : $pV = nRT$

$\therefore p = \frac{0.393 \times 8.31 \times (273+17)}{5.55 \times 10^{-3}}$

$p = 1.7 \times 10^5$ Pa so

allowed P range $1.6 \times 10^5 \rightarrow 2.1 \times 10^5$

So its in the range

**4** A cola drink of mass 0.200 kg at a temperature of 3.0 °C is poured into a glass beaker. The beaker has a mass of 0.250 kg and is initially at a temperature of 30.0 °C.

specific heat capacity of glass = 840 J $kg^{-1}K^{-1}$
specific heat capacity of cola = 4190 J $kg^{-1}K^{-1}$

(i) Show that the final temperature, $T_f$, of the cola drink is about 8 °C when it reaches thermal equilibrium with the beaker.
Assume no heat is gained from or lost to the surroundings.

heat energy supplied by glass=heat energy gained by cola

$m_g c_g \Delta\theta_g = m_c c_c \Delta\theta_c$

$0.25 \times 840 (30 - T_f) = 0.2 \times 4190 \times (T_f - 3)$

$0.25 (30 - T_f) = T_f - 3$

$\Rightarrow T_f \approx 8.4°C$

for glass
$30 - T_f = \Delta\theta_g$
for cola
$T_f - 3 = \Delta\theta_c$

**(2)**

(ii) The cola drink and beaker are cooled from $T_f$ to a temperature of 3.0 °C by adding ice at a temperature of 0 °C.
Calculate the mass of ice added.
Assume no heat is gained from or lost to the surroundings.

specific heat capacity of water = 4190 J $kg^{-1}$ $K^{-1}$
specific latent heat of fusion of ice = $3.34 \times 10^5$ J $kg^{-1}$

gain by ice = loss by water

cola: $\Delta E = 0.2 \times 4190 \times 5.4 = m \times 3.34 \times 10^5$

0.014

mass ____________________ kg

**(3)**

**(Total 5 marks)**

# Mark schemes

**1** B

**[1]**

**2** **C**

**[1]**

**3** (a) The molecules (continually) move about in random motion✓

Collisions of molecules with each other and with the walls are elastic✓

Time in contact is small compared with time between collisions✓

The molecules move in straight lines between collisions✓

**ANY TWO**

*Allow reference to 'particles interact according to Newtonian mechanics'*

2

(b) Ideas of pressure = F / A and F = rate of change of momentum✓

Mean KE / rms speed / mean speed of air molecules increases✓

More collisions with the inside surface of the football each second✓

*Allow reference to 'Greater change in momentum for each collision'*

3

(c) Radius = 690 mm / 6.28) = 110 mm or $T$ = 290 K ✓ seen

volume of air = $5.55 \times 10^{-3}$ $m^3$✓

$n \times 29$(g) = 11.4 (g)✓ $n$ = 0.392 mol

Use of $pV = nRT = \dfrac{0.392 \times 8.31 \times 290}{5.55 \times 10^{-3}\ m^3}$ ✓

$p = 1.70 \times 10^5$ Pa ✓

Conclusion: Appropriate comparison of their value for $p$ with the requirement of the rule, ie whether their pressure above $1 \times 10^5$ Pa falls within the required band✓

*Allow ecf for their n V and T*✓

6

**[11]**

**4** (i) (heat supplied by glass = heat gained by cola)

(use of $m_g\, c_g\, \Delta T_g = m_c\, c_c\, \Delta T_c$)

*1st mark for RHS or LHS of substituted equation*

$0.250 \times 840 \times (30.0 - T_f) = 0.200 \times 4190 \times (T_f - 3.0)$ ✓

*2nd mark for 8.4°C*

$(210 \times 30 - 210\, t_f = 838\, T_f - 838 \times 3)$

$T_f = 8.4(1)$ (°C) ✓

*Alternatives:*

*8°C is substituted into equation (on either side shown will get mark)* ✓

*resulting in 4620J~4190J* ✓

*or*

*8°C substituted into LHS* ✓ *(produces ΔT = 5.5°C and hence)*

*= 8.5°C ~ 8°C* ✓

*8°C substituted into RHS* ✓

*(produces ΔT = 20°C and hence)*

*= 10°C ~ 8°C* ✓

**2**

(ii) (heat gained by ice = heat lost by glass + heat lost by cola)

*NB correct answer does not necessarily get full marks*

(heat gained by ice = $mc\Delta T + ml$)
heat gained by ice = $m \times 4190 \times 3.0 + m \times 3.34 \times 10^5$ ✓
(heat gained by ice = $m \times 346600$)

*3rd mark is only given if the previous 2 marks are awarded*

heat lost by glass + heat lost by cola
= 0.250 × 840 × (8.41 – 3.0) + 0.200 × 4190 × (8.41 – 3.0) ✓
(= 5670 J)

*(especially look for $m \times 4190 \times 3.0$)*

*the first two marks are given for the formation of the substituted equation not the calculated values*

$m$ (=5670 / 346600) = 0.016 (kg) ✓

*if $8^oC$ is used the final answer is 0.015 kg*

or (using cola returning to its original temperature)
(heat supplied by glass = heat gained by ice)
(heat gained by glass = 0.250 × 840 × (30.0 – 3.0))
heat gained by glass = 5670 (J) ✓
(heat used by ice = $mc\Delta T + ml$)
heat used by ice = $m(4190 \times 3.0 + 3.34 \times 10^5)$ ✓ (= $m$(346600))

$m$ (=5670 / 346600) = 0.016 (kg) ✓

**3**

**[5]**