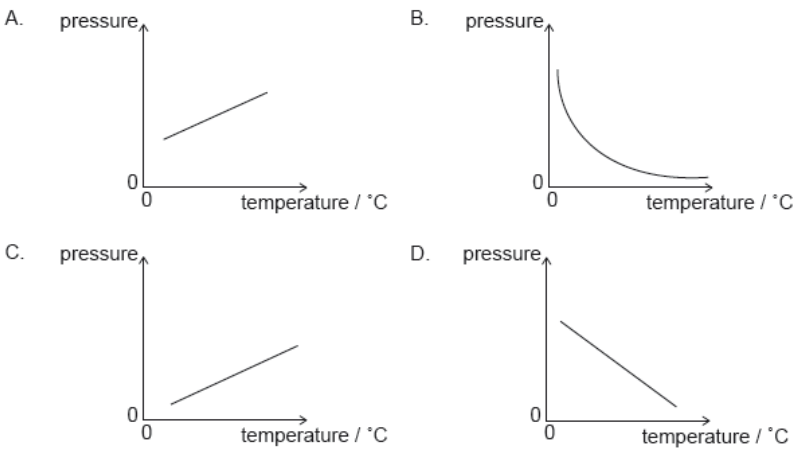
3_13_2 *[147 marks]*

1. A fixed mass of an ideal gas is trapped in a cylinder of constant volume and its temperature is varied. Which graph shows the variation of the pressure of the gas with temperature in degrees Celsius? *[1 mark]*



Markscheme

A

2. What are the units of the ratio $\frac{\text{specific heat capacity of copper}}{\text{specific latent heat of vaporization of copper}}$? *[1 mark]*

A. no units

B. k

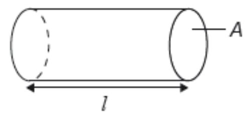
C. k^{-1}

D. k^{-2}

Markscheme

C

3. A sealed cylinder of length l and cross-sectional area A contains N molecules of an ideal gas at kelvin temperature T. *[1 mark]*



What is the force acting on the area of the cylinder marked A due to the gas?

A. $\frac{NRT}{l}$

B. $\frac{NRT}{lA}$

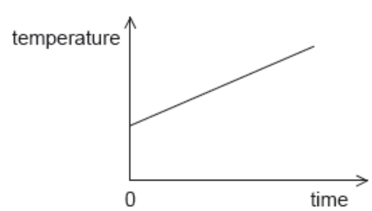
C. $\frac{Nk_BT}{lA}$

D. $\frac{Nk_BT}{l}$

Markscheme

D

4. The graph shows how the temperature of a liquid varies with time when energy is supplied to the liquid at a constant rate P. The gradient of the graph is K and the liquid has a specific heat capacity c. *[1 mark]*



What is the mass of the liquid?

A. $\frac{P}{cK}$

B. $\frac{PK}{c}$

C. $\frac{Pc}{K}$

D. $\frac{cK}{P}$

Markscheme

A

5. A container that contains a fixed mass of an ideal gas is at rest on a truck. The truck now moves away horizontally at a constant velocity. What is the change, if any, in the internal energy of the gas and the change, if any, in the temperature of the gas when the truck has been travelling for some time? *[1 mark]*

	Change in internal energy	Change in temperature
A.	unchanged	unchanged
B.	unchanged	increased
C.	increased	unchanged
D.	increased	increased

Markscheme

A

6. A sealed container contains water at 5 °C and ice at 0 °C. This system is thermally isolated from its surroundings. What happens to the total internal energy of the system? *[1 mark]*

A. It remains the same.

B. It decreases.

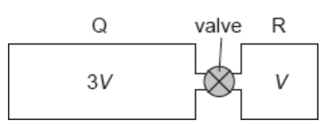
C. It increases until the ice melts and then remains the same.

D. It increases.

Markscheme

A

7. Q and R are two rigid containers of volume 3 V and V respectively containing molecules of the same ideal gas initially at the same temperature. The gas pressures in Q and R are p and 3p respectively. The containers are connected through a valve of negligible volume that is initially closed. *[1 mark]*



The valve is opened in such a way that the temperature of the gases does not change. What is the change of pressure in Q?

A. $+p$

B. $\frac{+p}{2}$

C. $\frac{-p}{2}$

D. $-p$

Markscheme

B

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.

8a. Calculate the pressure of the gas. *[1 mark]*

Markscheme

«$\frac{3.0\times8.31\times290}{0.15}$»

48 «kPa»

[1 mark]

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}.

8b. Calculate, in kg, the mass of the gas. *[1 mark]*

Markscheme

mass = «$\frac{860}{3100\times23}$» 0.012 «kg»

*Award **[1]** for a bald correct answer.*

[1 mark]

8c. Calculate the average kinetic energy of the particles of the gas. *[1 mark]*

Markscheme

$\frac{3}{2}$ 1.38 × 10^{-23} × 313 = 6.5 × 10^{-21} «J»

[1 mark]

8d. Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. *[3 marks]*

Markscheme

larger temperature implies larger (average) speed/larger (average) KE of molecules/particles/atoms

increased force/momentum transferred to walls (per collision) / more frequent collisions with walls

increased force leads to increased pressure because P = F/A (as area remains constant)

Ignore any mention of PV = nRT.

[3 marks]

An ideal monatomic gas is kept in a container of volume 2.1×10^{-4} m^3, temperature 310 K and pressure 5.3×10^5 Pa.

9a. State what is meant by an ideal gas. *[1 mark]*

Markscheme

a gas in which there are no intermolecular forces

OR

a gas that obeys the ideal gas law/all gas laws at all pressures, volumes and temperatures

OR

molecules have zero PE/only KE

Accept atoms/particles.

[1 mark]

9b. Calculate the number of atoms in the gas. *[1 mark]*

Markscheme

N = « $\frac{pV}{kT} = \frac{5.3 \times 10^5 \times 2.1 \times 10^{-4}}{1.38 \times 10^{-23} \times 310}$ » 2.6×10^{22}

[1 mark]

9c. Calculate, in J, the internal energy of the gas. *[2 marks]*

Markscheme

«For one atom $U = \frac{3}{2}kT$» $\frac{3}{2} \times 1.38 \times 10^{-23} \times 310$ / 6.4×10^{-21} «J»

U = «$2.6 \times 10^{22} \times \frac{3}{2} \times 1.38 \times 10^{-23} \times 310$» 170 «J»

Allow ECF from (a)(ii)

*Award **[2]** for a bald correct answer*

Allow use of $U = \frac{3}{2}pV$

[2 marks]

The volume of the gas in (a) is increased to 6.8×10^{-4} m^3 at constant temperature.

9d. Calculate, in Pa, the new pressure of the gas. *[1 mark]*

Markscheme

p_2 = «$5.3 \times 10^5 \times \frac{2.1 \times 10^{-4}}{6.8 \times 10^{-4}}$» 1.6×10^5 «Pa»

[1 mark]

9e. Explain, in terms of molecular motion, this change in pressure. *[2 marks]*

Markscheme

«volume has increased and» average velocity/KE remains unchanged

«so» molecules collide with the walls less frequently/longer time between collisions with the walls

«hence» rate of change of momentum at wall has decreased

«and so pressure has decreased»

The idea of average must be included

Decrease in number of collisions is not sufficient for MP2. Time must be included.

Accept atoms/particles.

[2 marks]

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}.

10a. Determine, in kJ, the total kinetic energy of the particles of the gas. *[3 marks]*

Markscheme

ALTERNATIVE 1

average kinetic energy = $\frac{3}{2}1.38 \times 10^{-23} \times 313 = 6.5 \times 10^{-21}$ «J»

number of particles = $3.0 \times 6.02 \times 10^{23} = 1.8 \times 10^{24}$

total kinetic energy = $1.8 \times 10^{24} \times 6.5 \times 10^{-21} = 12$ «kJ»

ALTERNATIVE 2

ideal gas so $U = KE$

$KE = \frac{3}{2}8.31 \times 131 \times 3$

total kinetic energy = 12 «kJ»

[3 marks]

10b. Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. *[3 marks]*

Markscheme

larger temperature implies larger (average) speed/larger (average) KE of molecules/particles/atoms

increased force/momentum transferred to walls (per collision) / more frequent collisions with walls

increased force leads to increased pressure because P = F/A (as area remains constant)

Ignore any mention of PV = nRT.

[3 marks]

11a. State what is meant by an ideal gas. *[1 mark]*

Markscheme

a gas in which there are no intermolecular forces

OR

a gas that obeys the ideal gas law/all gas laws at all pressures, volumes and temperatures

OR

molecules have zero PE/only KE

Accept atoms/particles.

[1 mark]

11b. Calculate the number of atoms in the gas. *[1 mark]*

Markscheme

N = «$\frac{pV}{kT} = \frac{5.3\times10^{5}\times2.1\times10^{-4}}{1.38\times10^{-23}\times310}$» 2.6×10^{22}

[1 mark]

11c. Calculate, in J, the internal energy of the gas. *[2 marks]*

Markscheme

«For one atom $U = \frac{3}{2}kT$» $\frac{3}{2} \times 1.38 \times 10^{-23} \times 310$ / 6.4×10^{-21} «J»

U = «$2.6 \times 10^{22} \times \frac{3}{2} \times 1.38 \times 10^{-23} \times 310$» 170 «J»

Allow ECF from (a)(ii)

*Award **[2]** for a bald correct answer*

Allow use of $U = \frac{3}{2}pV$

[2 marks]

11d. Calculate, in Pa, the new pressure of the gas. *[1 mark]*

Markscheme

p_2 = «$5.3 \times 10^5 \times \frac{2.1\times10^{-4}}{6.8\times10^{-4}}$» 1.6×10^5 «Pa»

[1 mark]

11e. Explain, in terms of molecular motion, this change in pressure. *[2 marks]*

Markscheme

«volume has increased and» average velocity/KE remains unchanged

«so» molecules collide with the walls less frequently/longer time between collisions with the walls

«hence» rate of change of momentum at wall has decreased

«and so pressure has decreased»

The idea of average must be included

Decrease in number of collisions is not sufficient for MP2. Time must be included.

Accept atoms/particles.

[2 marks]

12. A 1.0 kW heater supplies energy to a liquid of mass 0.50 kg. The temperature of the liquid changes by 80 K in a time of 200 s. The specific heat capacity of the liquid is 4.0 kJ kg^{-1} K^{-1}. What is the average power lost by the liquid? *[1 mark]*

A. 0

B. 200 W

C. 800 W

D. 1600 W

Markscheme

B

13. Under what conditions of pressure and temperature does a real gas approximate to an ideal gas? *[1 mark]*

	Pressure	Temperature
A.	high	high
B.	high	low
C.	low	high
D.	low	low

Markscheme

C

14. What does the constant *n* represent in the equation of state for an ideal gas $pV = nRT$? *[1 mark]*

A. The number of atoms in the gas

B. The number of moles of the gas

C. The number of molecules of the gas

D. The number of particles in the gas

Markscheme

B

15. Unpolarized light of intensity I_0 is incident on a polarizing filter. Light from this filter is incident on a second filter, which has its axis of polarization at 30˚ to that of the first filter. *[1 mark]*

The value of cos 30˚ is $\frac{\sqrt{3}}{2}$. What is the intensity of the light emerging through the second filter?

A. $\frac{\sqrt{3}}{2} I_0$

B. $\frac{3}{2} I_0$

C. $\frac{3}{4} I_0$

D. $\frac{3}{8} I_0$

Markscheme

D

16. The fraction of the internal energy that is due to molecular vibration varies in the different states of matter. What gives the order from highest fraction to lowest fraction of internal energy due to molecular vibration? *[1 mark]*

A. liquid > gas > solid

B. solid > liquid > gas

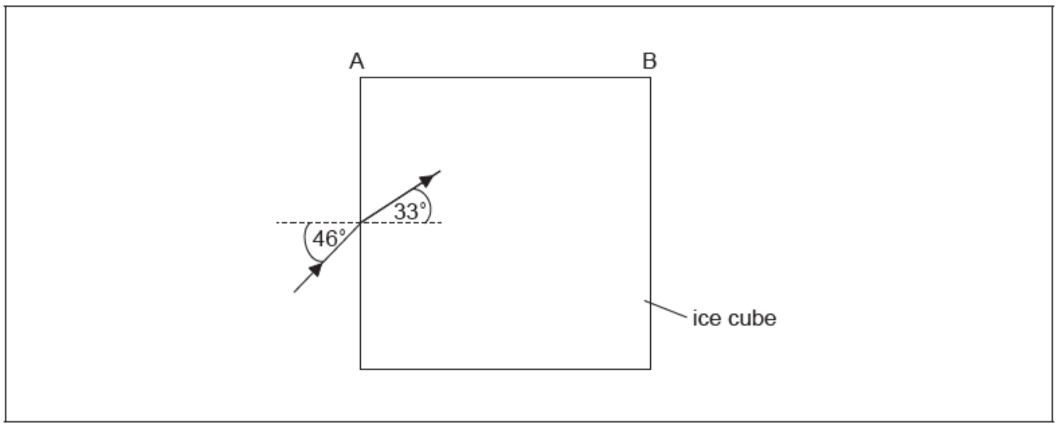
C. solid > gas > liquid

D. gas > liquid > solid

Markscheme

B

A large cube is formed from ice. A light ray is incident from a vacuum at an angle of 46˚ to the normal on one surface of the cube. The light ray is parallel to the plane of one of the sides of the cube. The angle of refraction inside the cube is 33˚.



17a. Calculate the speed of light inside the ice cube. *[2 marks]*

Markscheme

«$v = c\frac{\sin i}{\sin r}$ =» $\frac{3\times10^8\times\sin(33)}{\sin(46)}$

2.3×10^8 «m s^{-1}»

17b. Show that no light emerges from side AB. *[3 marks]*

Markscheme

light strikes AB at an angle of 57°

critical angle is «$\sin^{-1}\left(\frac{2.3}{3}\right)$ =» 50.1°

49.2° from unrounded value

angle of incidence is greater than critical angle so total internal reflection

OR

light strikes AB at an angle of 57°

calculation showing sin of "refracted angle" = 1.1

statement that since 1.1>1 the angle does not exist and the light does not emerge

[Max 3 marks]

17c. Sketch, on the diagram, the subsequent path of the light ray. *[2 marks]*

Markscheme

total internal reflection shown

ray emerges at opposite face to incidence

Judge angle of incidence=angle of reflection by eye or accept correctly labelled angles

With sensible refraction in correct direction

Each side of the ice cube is 0.75 m in length. The initial temperature of the ice cube is –20 °C.

17d. Determine the energy required to melt all of the ice from –20 °C to water at a temperature of 0 °C. *[4 marks]*

Specific latent heat of fusion of ice = 330 kJ kg $^{-1}$
Specific heat capacity of ice = 2.1 kJ kg $^{-1}$ k^{-1}
Density of ice = 920 kg m $^{-3}$

Markscheme

mass = «*volume* x *density*» $(0.75)^3$ x 920 «= 388 kg»

energy required to raise temperature = 388 x 2100 x 20 «= 1.63 x 10 ^{7} J»

energy required to melt = 388 x 330 x 10 ^{3} «= 1.28 x 10^8 J»

1.4 x 10^8 «J» ***OR*** 1.4 x 10^5 «kJ»

Accept any consistent units

Award ***[3 max]*** *for answer which uses density as 1000 kg^{-3} (1.5× 10^8 «J»)*

17e. Outline the difference between the molecular structure of a solid and a liquid. *[1 mark]*

Markscheme

in solid state, nearest neighbour molecules cannot exchange places/have fixed positions/are closer to each other/have regular pattern/have stronger forces of attraction

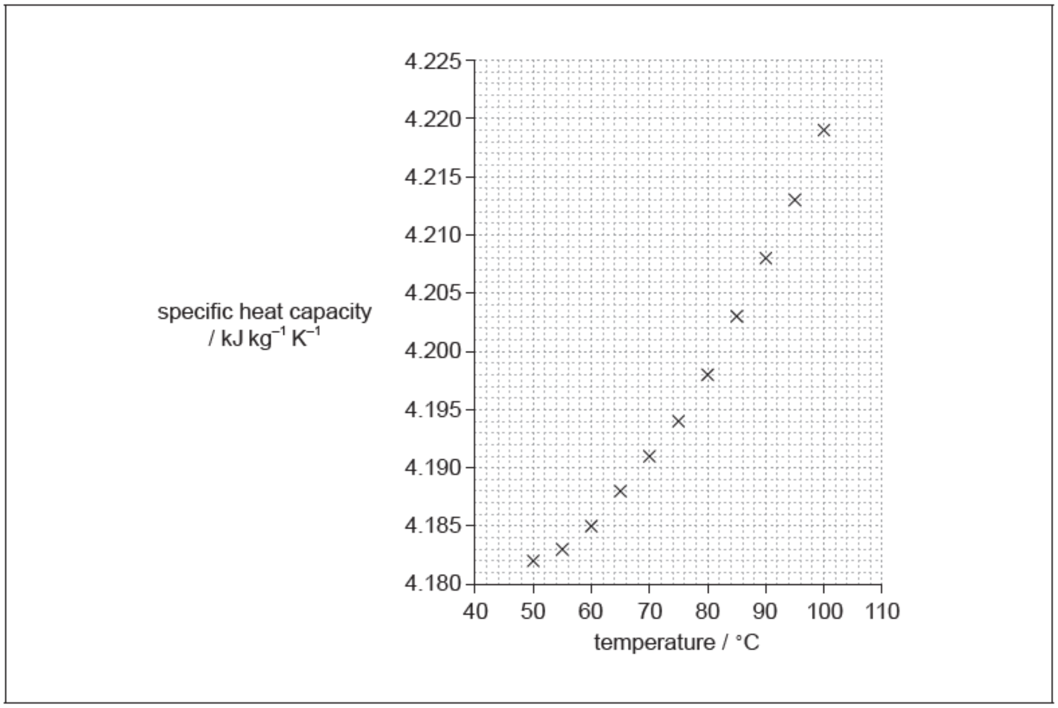
in liquid, bonds between molecules can be broken and re-form

OWTTE

Accept converse argument for liquids

[Max 1 Mark]

In an experiment, data were collected on the variation of specific heat capacity of water with temperature. The graph of the plotted data is shown.



18a. Draw the line of best-fit for the data. *[1 mark]*

Markscheme

single smooth curve passing through all data points

Do not accept straight lines joining the dots

Curve must touch some part of every x

18b. Determine the gradient of the line at a temperature of 80 °C. *[3 marks]*

Markscheme

tangent drawn at 80 °C

gradient values separated by minimum of 20 °C

9.0×10^{-4} «kJ kg^{-1} K^{-2}»

Do not accept tangent unless "ruler" straight.

Tangent line must be touching the curve drawn for MP1 to be awarded.

Accept values between 7.0×10^{-4} and 10×10^{-4}.

Accept working in J, giving 0.7 to 1.0

18c. State the unit for the quantity represented by the gradient in your answer to (b)(i). *[1 mark]*

Markscheme

kJ kg^{-1} K^{-2}

Accept J instead of kJ

Accept °C^{-2} instead of K^{-2}

Accept °C^{-1} K^{-1} instead of K^{-2}

Accept C for °C

The uncertainty in the values for specific heat capacity is 5%.

Water of mass (100 ± 2) g is heated from (75.0 ± 0.5) °C to (85.0 ± 0.5) °C.

18d. Calculate the energy required to raise the temperature of the water from 75 °C to 85 °C. *[1 mark]*

Markscheme

«0.1 x 4.198 x 10 =» 4.198 «kJ» ***or*** 4198 «J»

Accept values between 4.19 and 4.21

18e. Using an appropriate error calculation, justify the number of significant figures that should be used for your answer to (c)(i). *[3 marks]*

Markscheme

percentage uncertainty in ΔT = 10%

«2% + 5% + 10%» = 17%

absolute uncertainty «0.17 × 4.198 =» 0.7 «kJ» therefore 2 sig figs

OR

absolute uncertainty to more than 1 sig fig and consistent final answer

Allow fractional uncertainties in MP1 and MP2

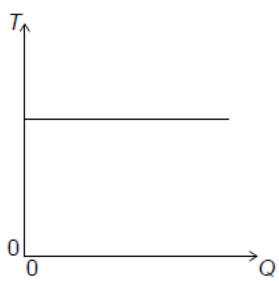
Watch for ECF from (c)(i)

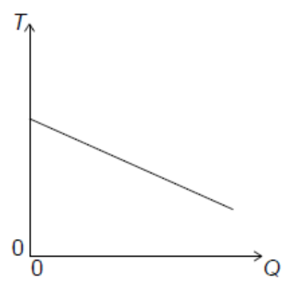
Watch for ECF from MP1

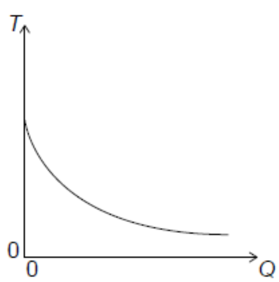
Watch for ECF from MP2

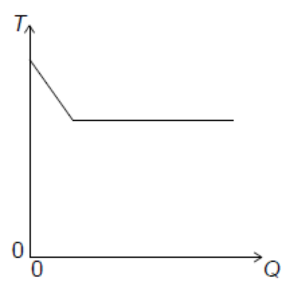
Do not accept an answer without justification

19. A liquid is initially at its freezing point. Energy is removed at a uniform rate from the liquid until it freezes completely. *[1 mark]*
Which graph shows how the temperature T of the liquid varies with the energy Q removed from the liquid?

A.


B.


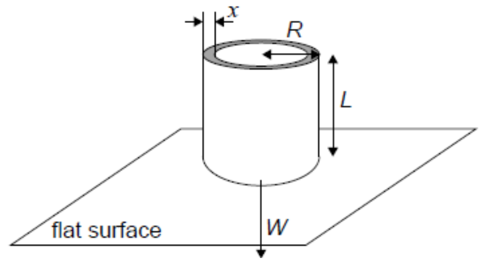
C.


D.


Markscheme

A

20. A thin-walled cylinder of weight *W*, open at both ends, rests on a flat surface. The cylinder has a height *L*, an average radius *R* and a thickness *x* where *R* is much greater than *x*. *[1 mark]*



What is the pressure exerted by the cylinder walls on the flat surface?

A. $\frac{W}{2\pi Rx}$

B. $\frac{W}{\pi R^2 x}$

C. $\frac{W}{\pi R^2}$

D. $\frac{W}{\pi R^2 L}$

Markscheme

A

21. A fixed mass of an ideal gas in a closed container with a movable piston initially occupies a volume *V*. The position of the piston is changed, so that the mean kinetic energy of the particles in the gas is doubled and the pressure remains constant. *[1 mark]*

What is the new volume of the gas?

A. $\frac{V}{4}$

B. $\frac{V}{2}$

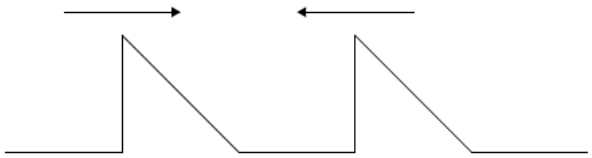
C. $2V$

D. $4V$

Markscheme

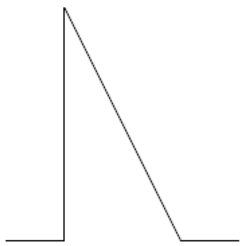
C

22. Two pulses are travelling towards each other. *[1 mark]*

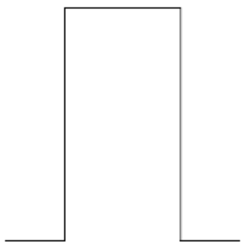


What is a possible pulse shape when the pulses overlap?

A.

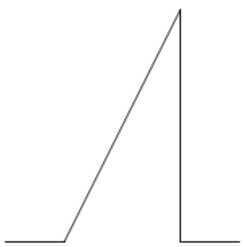


B.



C.

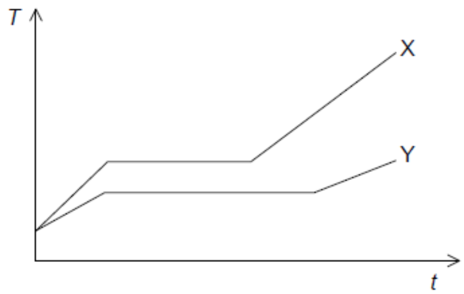
D.



Markscheme

A

23. The graph shows the variation with time t of the temperature T of two samples, X and Y. X and Y have the same mass and are initially in the solid phase. Thermal energy is being provided to X and Y at the same constant rate. *[1 mark]*



What is the correct comparison of the specific latent heats L_X and L_Y and specific heat capacities in the liquid phase c_X and c_Y of X and Y?

A.	$L_X > L_Y$	$c_X > c_Y$
B.	$L_X > L_Y$	$c_X < c_Y$
C.	$L_X < L_Y$	$c_X > c_Y$
D.	$L_X < L_Y$	$c_X < c_Y$

Markscheme

D

24. A mass m of ice at a temperature of –5 °C is changed into water at a temperature of 50 °C. *[1 mark]*

Specific heat capacity of ice = c_i
Specific heat capacity of water = c_w
Specific latent heat of fusion of ice = L

Which expression gives the energy needed for this change to occur?

A. $55\ m\,c_w + m\,L$

B. $55\ m\,c_i + 5\ m\,L$

C. $5\ m\,c_i + 50\ m\,c_w + m\,L$

D. $5\ m\,c_i + 50\ m\,c_w + 5\ m\,L$

Markscheme

C

25. A sealed container contains a mixture of oxygen and nitrogen gas. *[1 mark]*
The ratio $\frac{\text{mass of an oxygen molecule}}{\text{mass of a nitrogen molecule}}$ is $\frac{8}{7}$.

The ratio $\frac{\text{average kinetic energy of oxygen molecules}}{\text{average kinetic energy of nitrogen molecules}}$ is

A. 1.

B. $\frac{7}{8}$.

C. $\frac{8}{7}$.

D. dependent on the concentration of each gas.

Markscheme

A

---

26. An ideal gas has a volume of 15 ml, a temperature of 20 °C and a pressure of 100 kPa. The volume of the gas is reduced to 5 ml and the temperature is raised to 40 °C. What is the new pressure of the gas? *[1 mark]*

A. 600 kPa

B. 320 kPa

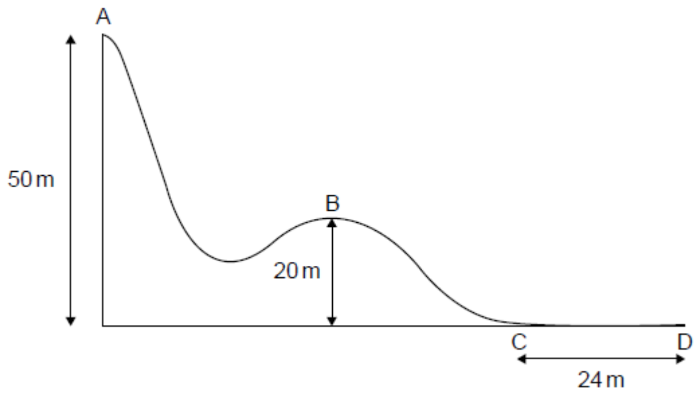
C. 200 kPa

D. 35 kPa

Markscheme

B

The diagram below shows part of a downhill ski course which starts at point A, 50 m above level ground. Point B is 20 m above level ground.



A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

27a. From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. Show that the velocity at B is 12 m s^{-1}. *[2 marks]*

Markscheme

$\frac{1}{2}v^2 = 0.24\,\text{gh}$

$v = 11.9$ «m s^{-1}»

Award GPE lost = 65 × 9.81 × 30 = «19130 J»

Must see the 11.9 value for MP2, not simply 12.

Allow g = 9.8 ms^{-2}.

27b. Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. Distinguish between internal energy and temperature. *[2 marks]*

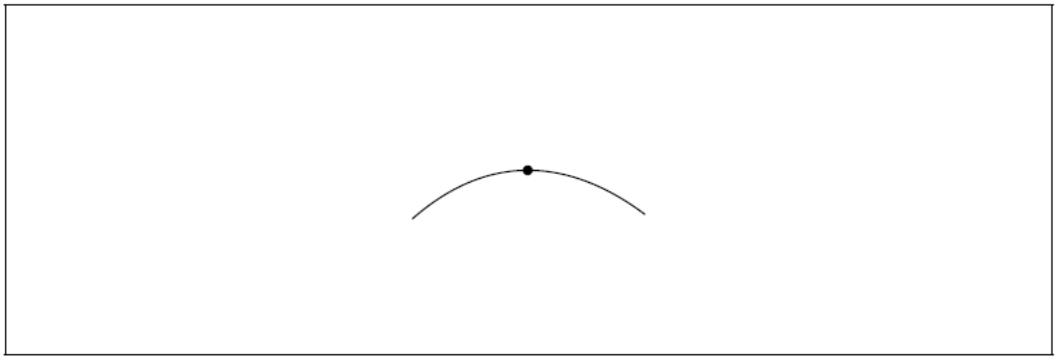
Markscheme

internal energy is the total KE «and PE» of the molecules/particles/atoms in an object

temperature is a measure of the average KE of the molecules/particles/atoms

*Award **[1 max]** if there is no mention of molecules/particles/atoms.*

27c. The dot on the following diagram represents the skier as she passes point B. Draw and label the vertical forces acting on the skier. *[2 marks]*



Markscheme

arrow vertically downwards from dot labelled weight/W/mg/gravitational force/F_g/$F_{gravitational}$ ***AND*** arrow vertically upwards from dot labelled reaction force/R/normal contact force/N/F_N

W > R

Do not allow gravity.
Do not award MP1 if additional 'centripetal' force arrow is added.
Arrows must connect to dot.
Ignore any horizontal arrow labelled friction.
Judge by eye for MP2. Arrows do not have to be correctly labelled or connect to dot for MP2.

27d. The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. *[3 marks]*

Markscheme

ALTERNATIVE 1

recognition that centripetal force is required / $\frac{mv^2}{r}$ seen

= 468 «N»

W/640 N (weight) is larger than the centripetal force required, so the skier does not lose contact with the ground

ALTERNATIVE 2

recognition that centripetal acceleration is required / $\frac{v^2}{r}$ seen

a = 7.2 «ms^{-2}»

g is larger than the centripetal acceleration required, so the skier does not lose contact with the ground

ALTERNATIVE 3

recognition that to lose contact with the ground centripetal force ≥ weight

calculation that v ≥ 14 «ms^{-1}»

comment that 12 «ms^{-1}» is less than 14 «ms^{-1}» so the skier does not lose contact with the ground

ALTERNATIVE 4

recognition that centripetal force is required / $\frac{mv^2}{r}$ seen

calculation that reaction force = 172 «N»

reaction force > 0 so the skier does not lose contact with the ground

Do not award a mark for the bald statement that the skier does not lose contact with the ground.

27e. The skier reaches point C with a speed of 8.2 m s^{-1}. She stops after a distance of 24 m at point D. *[3 marks]*

Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected.

Markscheme

ALTERNATIVE 1
$0 = 8.2^2 + 2 \times a \times 24$ therefore a = «–»1.40 «m s^{-2}»

friction force = ma = 65 × 1.4 = 91 «N»

coefficient of friction = $\frac{91}{65 \times 9.81}$ = 0.14

ALTERNATIVE 2
$KE = \frac{1}{2}mv^2 = 0.5 \times 65 \times 8.2^2 = 2185$ «J»

friction force = KE/distance = 2185/24 = 91 «N»

coefficient of friction = $\frac{91}{65 \times 9.81}$ = 0.14

Allow ECF from MP1.

At the side of the course flexible safety nets are used. Another skier of mass 76 kg falls normally into the safety net with speed 9.6 m s^{-1}.

27f. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. *[2 marks]*

Markscheme

«76 × 9.6»= 730
Ns ***OR*** kg ms^{-1}

27g. Explain, with reference to change in momentum, why a flexible safety net is less likely to harm the skier than a rigid barrier. *[2 marks]*

Markscheme

safety net extends stopping time

$F = \frac{\Delta p}{\Delta t}$ therefore F is smaller «with safety net»

OR

force is proportional to rate of change of momentum therefore F is smaller «with safety net»

Accept reverse argument.

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).

28a. Write down the missing values in the nuclear equation for this decay. *[1 mark]*

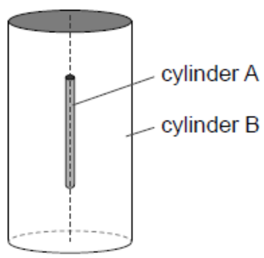
$$^{226}_{88}\mathrm{Ra} \rightarrow {}^{\cdots\cdots}_{86}\mathrm{Rn} + {}^{\cdots\cdots}_{2}\alpha$$

Markscheme

222 ***AND*** 4

Both needed.

28b. Rutherford and Royds put some pure radium-226 in a small closed cylinder A. Cylinder A is fixed in the centre of a larger closed cylinder B. *[1 mark]*



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.

The wall of cylinder A is made from glass. Outline why this glass wall had to be very thin.

Markscheme

alpha particles highly ionizing
OR
alpha particles have a low penetration power
OR
thin glass increases probability of alpha crossing glass
OR
decreases probability of alpha striking atom/nucleus/molecule

28c. Rutherford and Royds expected 2.7 x 10^{15} alpha particles to be emitted during the experiment. 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. *[3 marks]*

Markscheme

conversion of temperature to 291 K

p = 4.5 x 10^{-9} x 8.31 x «$\frac{2.91}{1.3\times10^{-5}}$»

OR

p = 2.7 x 10^{15} x 1.38 x 10^{-23} x «$\frac{2.91}{1.3\times10^{-5}}$»

0.83 or 0.84 «Pa»

28d. Rutherford and Royds identified the helium gas in cylinder B by observing its emission spectrum. Outline, with reference to atomic energy levels, how an emission spectrum is formed. *[3 marks]*

Markscheme

electron/atom drops from high energy state/level to low state

energy levels are discrete

wavelength/frequency of photon is related to energy change ***or*** quotes $E = hf$ ***or*** $E = \frac{hc}{\lambda}$

and is therefore also discrete

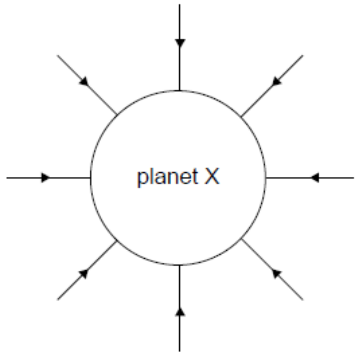
28e. The work was first reported in a peer-reviewed scientific journal. Outline why Rutherford and Royds chose to publish their work in this way. *[1 mark]*

Markscheme

peer review guarantees the validity of the work
OR
means that readers have confidence in the validity of work

OWTTE

The diagram shows the gravitational field lines of planet X.

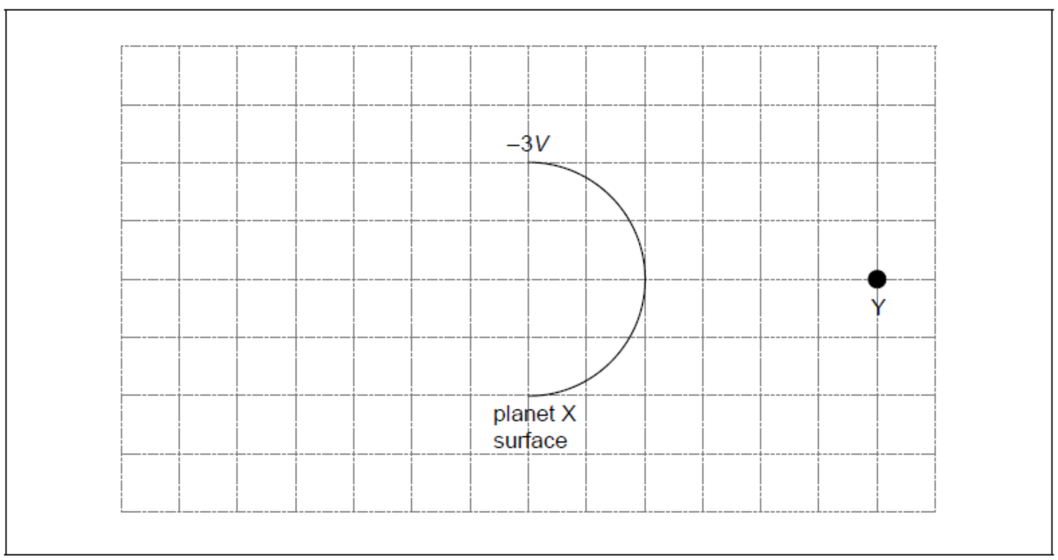


29a. Outline how this diagram shows that the gravitational field strength of planet X decreases with distance from the surface. *[1 mark]*

Markscheme

the field lines/arrows are further apart at greater distances from the surface

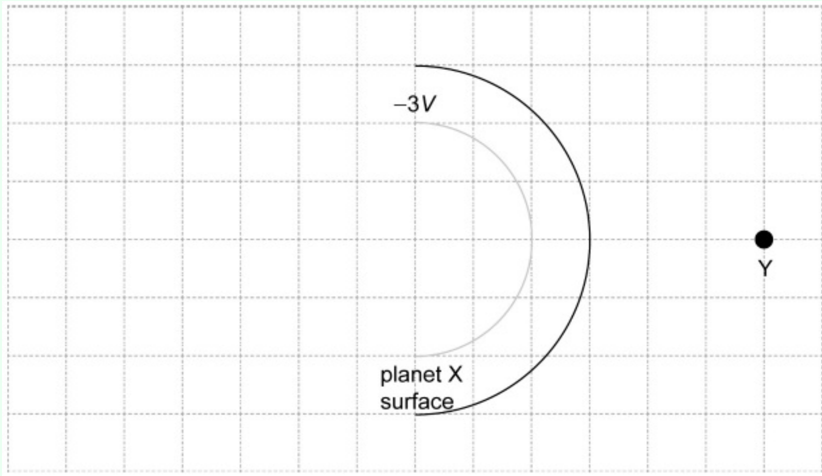
29b. The diagram shows part of the surface of planet X. The gravitational potential at the surface of planet X is $-3V$ and the gravitational potential at point Y is $-V$. *[2 marks]*



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

Markscheme

circle centred on Planet X
three units from Planet X centre



29c. 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 marks]*

Markscheme

loss in gravitational potential = $\frac{6.67\times10^{-11}\times3.1\times10^{21}}{1.2\times10^{6}}$

«= 1.72×10^{5} JKg^{-1}»

equate to $\frac{1}{2}v^2$

v = 590 «m s^{-1}»

Allow ECF from MP1.

29d. 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 marks]*

Markscheme

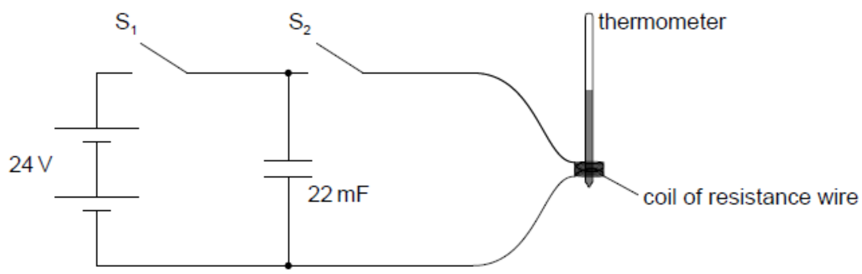
available energy to melt one kg 1.72×10^5 «J»

fraction that melts is $\frac{1.72 \times 10^5}{3.3 \times 10^5}$ = 0.52 ***OR*** 52%

Allow ECF from MP1.

Allow 53% from use of 590 ms^{-1}.

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.

30a. The capacitance of the capacitor is 22 mF. Calculate the energy stored in the capacitor when it is fully charged. *[1 mark]*

Markscheme

«$\frac{1}{2}CV^2 = \frac{1}{2} \times 0.22 \times 24^2$» = «J»

30b. 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 marks]*

Markscheme

$\frac{1}{100} = e^{-\frac{t}{8.0 \times 0.022}}$

$\ln 0.01 = -\frac{t}{8.0 \times 0.022}$

0.81 «s»

30c. 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 marks]*

Markscheme

$c = \frac{Q}{m \times \Delta T}$

OR

$\frac{6.3}{0.00061 \times 28}$

370 J kg^{-1} K^{-1}

Allow ECF from 3(a) for energy transferred.

Correct answer only to include correct unit that matches answer power of ten.

Allow use of g and kJ in unit but must match numerical answer, eg: 0.37 J kg $^{-1}$ K^{-1} receives ***[1]***

30d. 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 marks]*

Markscheme

ALTERNATIVE 1

some thermal energy will be transferred to surroundings/along connecting wires/to thermometer

estimate «of specific heat capacity by student» will be larger «than accepted value»

ALTERNATIVE 2

not all energy transferred as capacitor did not fully discharge

so estimate «of specific heat capacity by student» will be larger «than accepted value»

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).

31a. Write down the nuclear equation for this decay. *[2 marks]*

Markscheme

$^{4}_{2}\alpha$

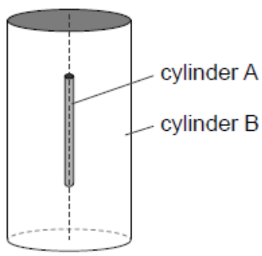
OR

$^{4}_{2}\mathrm{He}$

$^{222}_{86}\mathrm{Rn}$

*These **must** be seen on the right-hand side of the equation.*

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}.

31b. Deduce that the activity of the radium-226 is almost constant during the experiment. *[2 marks]*

Markscheme

ALTERNATIVE 1

6 days is 5.18 x 10^5 s

activity after 6 days is $A_0 e^{-1.4 \times 10^{-11} \times 5.8 \times 10^5} \approx A_0$

OR

A = 0.9999927 A_0 ***or*** 0.9999927 λN_0

OR

states that index of e is so small that $\frac{A}{A_0}$ is ≈ 1

OR

$A - A_0 \approx 10^{-15}$ «s^{-1}»

ALTERNATIVE 2
shows half-life of the order of 10^{11} s or 5.0 x 10^{10} s

converts this to year «1600 y» or days and states half-life much longer than experiment compared to experiment

*Award **[1 max]** if calculations/substitutions have numerical slips but would lead to correct deduction.*

eg: failure to convert 6 days to seconds but correct substitution into equation will give MP2.

Allow working in days, but for MP1 must see conversion of λ or half-life to day^{-1}.

31c. Show that about 3 x 10^{15} alpha particles are emitted by the radium-226 in 6 days. *[3 marks]*

Markscheme

ALTERNATIVE 1

use of $A = \lambda N_0$

conversion to number of molecules = nN_A = 3.7 x 10^{20}

OR

initial activity = 5.2 x 10^9 «s^{-1}»

number emitted = (6 x 24 x 3600) x 1.4 x 10^{-11} x 3.7 x 10^{20} ***or*** 2.7 x 10^{15} alpha particles

ALTERNATIVE 2

use of $N = N_0 e^{-\lambda t}$

$N_0 = n \times N_A$ = 3.7 x 10^{20}

alpha particles emitted «= number of atoms disintegrated = $N - N_0$ =» $N_0 \left(1 - e^{-\lambda \times 6 \times 24 \times 3600}\right)$ ***or*** 2.7 x 10^{15} alpha particles

Must see correct substitution or answer to 2+ sf for MP3

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.

31d. The wall of cylinder A is made from glass. Outline why this glass wall had to be very thin. *[1 mark]*

Markscheme

alpha particles highly ionizing
OR
alpha particles have a low penetration power
OR
thin glass increases probability of alpha crossing glass
OR
decreases probability of alpha striking atom/nucleus/molecule

Do not allow reference to tunnelling.

31e. 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 marks]*

Markscheme

conversion of temperature to 291 K

$p = 4.5 \times 10^{-9} \times 8.31 \times$ «$\frac{291}{1.3\times10^{-5}}$»

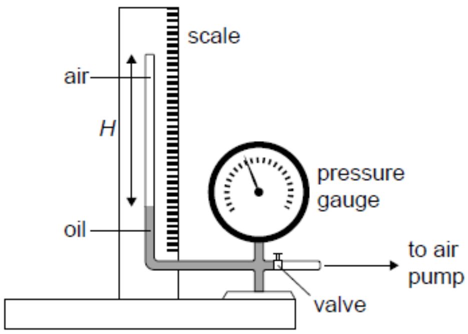
OR

$p = 2.7 \times 10^{15} \times 1.3 \times 10^{-23} \times$ «$\frac{291}{1.3\times10^{-5}}$»

0.83 ***or*** 0.84 «Pa»

Allow ECF for 2.7×10^{15} from (b)(ii).

The equipment shown in the diagram was used by a student to investigate the variation with volume, of the pressure *p* of air, at constant temperature. The air was trapped in a tube of constant cross-sectional area above a column of oil.



The pump forces oil to move up the tube decreasing the volume of the trapped air.

32a. The student measured the height *H* of the air column and the corresponding air pressure *p*. After each reduction in the volume the student waited for some time before measuring the pressure. Outline why this was necessary. *[1 mark]*

Markscheme

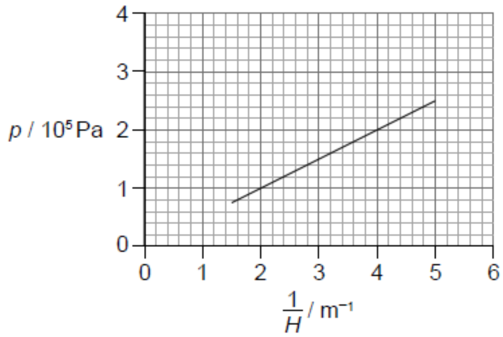
in order to keep the temperature constant

in order to allow the system to reach thermal equilibrium with the surroundings/OWTTE

Accept answers in terms of pressure or volume changes only if clearly related to reaching thermal equilibrium with the surroundings.

[1 mark]

32b. The following graph of p versus $\frac{1}{H}$ was obtained. Error bars were negligibly small. *[3 marks]*



The equation of the line of best fit is $p = a + \frac{b}{H}$.

Determine the value of b including an appropriate unit.

Markscheme

recognizes b as gradient

calculates b in range 4.7×10^4 to 5.3×10^4

Pa m

*Award **[2 max]** if POT error in b.*
Allow any correct SI unit, eg kg
s^{-2}.

[3 marks]

32c. Outline how the results of this experiment are consistent with the ideal gas law at constant temperature. *[2 marks]*

Markscheme

$V \propto H$ thus ideal gas law gives $p \propto \frac{1}{H}$

so graph **should be** «a straight line through origin,» as **observed**

[2 marks]

32d. The cross-sectional area of the tube is 1.3×10^{-3} m^2 and the temperature of air is 300 K. Estimate the number of moles of air in the tube. *[2 marks]*

Markscheme

$n = \frac{bA}{RT}$ ***OR*** correct substitution of one point from the graph

$n = \frac{5\times10^4\times1.3\times10^{-3}}{8.31\times300} = 0.026 \approx 0.03$

Answer must be to 1 or 2 SF.

Allow ECF from (b).

[2 marks]

32e. The equation in (b) may be used to predict the pressure of the air at extremely large values of $\frac{1}{H}$. Suggest why this will be an unreliable estimate of the pressure. *[2 marks]*

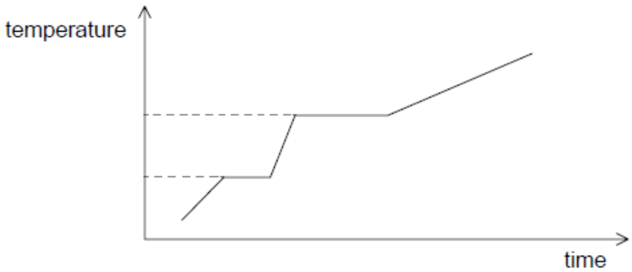
Markscheme

very large $\frac{1}{H}$ means very small volumes / very high pressures

at very small volumes the ideal gas does not apply
OR
at very small volumes some of the assumptions of the kinetic theory of gases do not hold

[2 marks]

33. Energy is supplied at a constant rate to a fixed mass of a material. The material begins as a solid. The graph shows the variation of the temperature of the material with time. *[1 mark]*



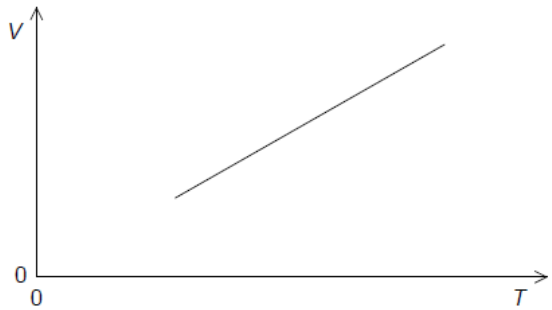
The specific heat capacities of the solid, liquid and gaseous forms of the material are c_s c_l and c_g respectively. What can be deduced about the values of c_s c_l and c_g?

A. $c_s > c_g > c_l$
B. $c_l > c_s > c_g$
C. $c_l > c_g > c_s$
D. $c_g > c_s > c_l$

Markscheme

D

34. An ideal gas of N molecules is maintained at a constant pressure p. The graph shows how the volume V of the gas varies with absolute temperature T. *[1 mark]*



What is the gradient of the graph?

A. $\frac{N}{p}$

B. $\frac{NR}{p}$

C. $\frac{Nk_B}{p}$

D. $\frac{N}{Rp}$

Markscheme

C

35. The pressure of a fixed mass of an ideal gas in a container is decreased at constant temperature. For the molecules of the gas there will be a decrease in *[1 mark]*

A. the mean square speed.
B. the number striking the container walls every second.
C. the force between them.
D. their diameter.

Markscheme

B

36a. Define *internal energy.* *[2 marks]*

Markscheme

mention of atoms/molecules/particles

sum/total of kinetic energy and «mutual/intermolecular» potential energy

Do not allow "kinetic energy and potential energy" bald.
Do not allow "sum of average ke and pe" unless clearly referring to total ensemble.

36b. 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. *[4 marks]*

(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 **one** reason why scientists find such models useful.

Markscheme

i
«intermolecular» potential energy/PE of an ideal gas is zero/negligible

ii
THIS IS FOR USE WITH AN ENGLISH SCRIPT ONLY
use of $T = \frac{PV}{nR}$ ***or*** $T = \frac{1.4 \times 21}{0.46 \times 8.31}$

Award mark for correct re-arrangement as shown here not for quotation of Data Booklet version.
*Award **[2]** for a bald correct answer in K.*
*Award **[2 max]** if correct 7.7 K seen followed by –265 °C and mark BOD. However, if only –265 °C seen, award **[1 max]**.*

7.7 K
Do not penalise use of "°K"

ii
THIS IS FOR USE WITH A SPANISH SCRIPT ONLY
$T = \frac{PV}{nR}$

$T = \frac{1.4 \times 2.1 \times 10^{-6}}{0.46 \times 8.31}$

T = 7.7 ×10^{-6} K
Award mark for correct re-arrangement as shown here not for quotation of Data Booklet version.
Uses correct unit conversion for volume
*Award **[2]** for a bald correct answer in K. Finds solution. Allow an ECF from MP2 if unit not converted, ie candidate uses 21 m3 and obtains 7.7 K*
Do not penalise use of "°K"

iii
models used to predict/hypothesize

explain

simulate

simplify/approximate
*Allow similar responses which have equivalent meanings. Response needs to identify **one** reason.*

37. 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. *[5 marks]*

(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.

Markscheme

i
«intermolecular» potential energy/PE of an ideal gas is zero/negligible

ii
THIS IS FOR USE WITH AN ENGLISH SCRIPT ONLY
use of $T = \frac{PV}{nR}$ ***or*** $T = \frac{1.4 \times 21}{0.46 \times 8.31}$
Award mark for correct re-arrangement as shown here not for quotation of Data Booklet version.
*Award **[2]** for a bald correct answer in K.*
*Award **[2 max]** if correct 7.7 K seen followed by –265 °C and mark BOD. However, if only –265 °C seen, award **[1 max]**.*

7.7K
Do not penalise use of "°K"

ii
THIS IS FOR USE WITH A SPANISH SCRIPT ONLY
$T = \frac{PV}{nR}$
Award mark for correct re-arrangement as shown here not for quotation of Data Booklet version.

$T = \frac{1.4 \times 2.1 \times 10^{-6}}{0.46 \times 8.31}$
Uses correct unit conversion for volume

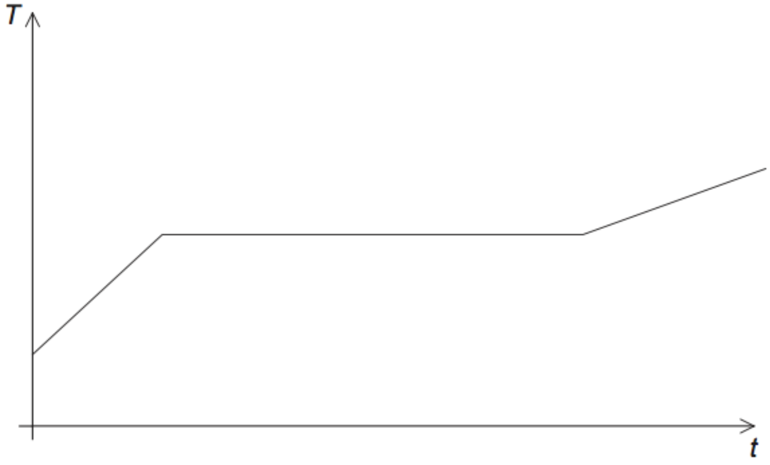
T = 7.7×10^{-6}K
*Award **[2]** for a bald correct answer in K. Finds solution. Allow an ECF from MP2 if unit not converted, ie candidate uses 21m3 and obtains 7.7 K*
Do not penalise use of "°K"

iii
«models used to»
predict/hypothesize / lead to further theories
*Response needs to identify **two** different reasons. (**N.B.** only one in SL).*

explain / help with understanding / help to visualize
Do not allow any response that is gas specific. The question is couched in general, nature of science terms and must be answered as such.

simulate
simplify/approximate

38. A substance is heated at constant power. The graph shows how the temperature *T* of the substance varies with time *t* as the state of the substance changes from liquid to gas. *[1 mark]*



What can be determined from the graph?

A. The specific heat capacity of the gas is smaller than the specific heat capacity of the liquid.

B. The specific heat capacity of the gas is larger than the specific heat capacity of the liquid.

C. The specific latent heat of fusion of the substance is less than its specific latent heat of vaporization.

D. The specific latent heat of fusion of the substance is larger than its specific latent heat of vaporization.

Markscheme

B

39. Which of the following is **not** an assumption of the kinetic model of ideal gases? *[1 mark]*

A. All particles in the gas have the same mass.

B. All particles in the gas have the same speed.

C. The duration of collisions between particles is very short.

D. Collisions with the walls of the container are elastic.

Markscheme

B

40. Under what conditions of density and pressure is a real gas best described by the equation of state for an ideal gas? *[1 mark]*

A. Low density and low pressure

B. Low density and high pressure

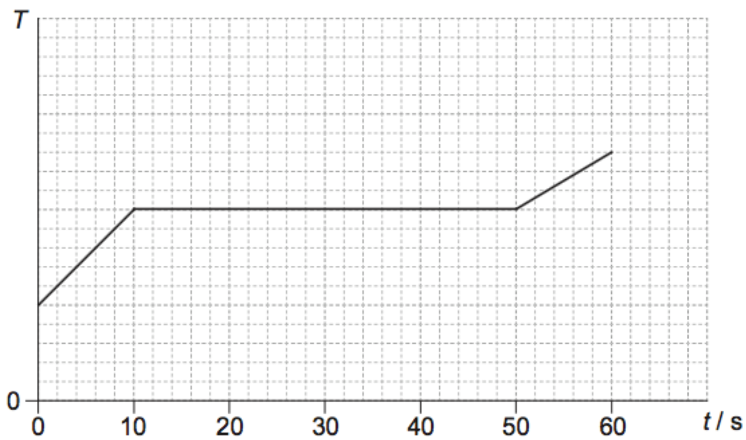
C. High density and low pressure

D. High density and high pressure

Markscheme

A

41. A container with 0.60kg of a liquid substance is placed on a heater at time *t=0*. The specific latent heat of vaporization of the substance is 200kJkg^{-1}. The graph shows the variation of the temperature *T* of the substance with time *t*. *[1 mark]*



What is the power of the heater?

A. 1200 W

B. 3000 W

C. 4800 W

D. 13 300 W

Markscheme

B