Natural Sciences Admissions Assessment

Section 2

Specimen Sample Questions:
Explained Answers

New Format for 2020

PHYSICS

1

The answer is option **C**.

This problem can be solved by considering the vertical and horizontal motion separately and using the equations of motion, since the acceleration is constant.

Vertically:

$$s = ut + \tfrac{1}{2}at^2$$

$$4 = \tfrac{1}{2}gt^2$$

$$t^2 = \frac{4}{5}$$

$$t = \frac{2}{\sqrt{5}} \text{ s}$$

Horizontally:

$$\text{distance} = \text{speed} \times \text{time}$$

$$\frac{6\sqrt{5}}{5} = \frac{2\sqrt{5}}{5}v$$

$$v = \frac{5 \times 6\sqrt{5}}{5 \times 2\sqrt{5}}$$

$$v = 3\,\text{m}\,\text{s}^{-1}$$

2

The answer is option **A**.

This problem can be solved by using $V = IR$ and resistivity = resistance $\times \frac{\text{cross-sectional area}}{\text{length}}$, $\rho = \frac{RA}{l}$

The current in the resistor is given by:

$$I = \frac{V}{R} = \frac{\text{pd across resistor}}{\text{resistance of resistor}} = \frac{1.0}{1.0 \times 10^3} = 1.0 \times 10^{-3} \, \text{A}$$

The wire and the resistor are connected in series so the current is the same in each of them.

The wire and the resistor act as a potential divider. The 1.2 V across the arrangement is shared between the wire and the resistor.

There is 1.0 V across the resistor so the pd across the wire is:

$$(1.2 - 1.0) = 0.20 \, \text{V}$$

Therefore the resistance of the wire is given by:

$$R = \frac{V}{I} = \frac{\text{pd across wire}}{\text{current in wire}} = \frac{0.2}{1.0 \times 10^{-3}} = 2.0 \times 10^2 \, \Omega$$

The resistivity is then:

$$\rho = \frac{RA}{l} = \frac{(2.0 \times 10^2) \times (0.020 \times 10^{-6})}{4.0} = 1.0 \times 10^{-6} \, \Omega \, \text{m}$$

3

The answer is option **A**.

This problem can be solved by considering each set of resistors and the internal resistance separately.

The combined resistance of the two $10\,\Omega$ resistors in parallel is given by:

$$\frac{1}{R_{total}} = \frac{1}{10\,\Omega} + \frac{1}{10\,\Omega} = \frac{1}{5\,\Omega}$$

$$R_{total} = \frac{10\,\Omega \times 10\,\Omega}{10\,\Omega + 10\,\Omega}$$

$$R_{total} = 5.0\,\Omega$$

The total resistance in the circuit, not including the internal resistance of the battery, is:

$$5.0\,\Omega + 3.0\,\Omega = 8.0\,\Omega$$

The total resistance in the circuit including the internal resistance of the battery is:

$$\frac{emf}{I} = \frac{20\,V}{2.0\,A} = 10\,\Omega$$

The internal resistance of the battery is $10\,\Omega - 8.0\,\Omega = 2.0\,\Omega$

4

The answer is option **C**.

This problem can be solved by first considering one cable individually.

Calculate the force applied by one of the cables by combining the equation for Young modulus:

$$E = \frac{\sigma}{\varepsilon}$$

and the equation defining stress:

$$\sigma = \frac{F}{A}$$

to give:

$$\sigma = \varepsilon E = \frac{F}{A}$$

$$F = \varepsilon E A$$

$$F = 0.0025 \times 2.0 \times 10^{11} \times 2.0 \times 10^{-4}$$

$$F = 1.0 \times 10^{5}\,\text{N}$$

The four cables are connected in parallel so the total force on the boulder is $4.0 \times 10^{5}\,\text{N} = 400\,\text{kN}$.

The boulder is moving at constant velocity so the resultant force is zero and the frictional force is equal to the total pulling force. Therefore the magnitude of the frictional force is also $400\,\text{kN}$.

Power transfer is given by $P = Fv = 400\,000\,\text{N} \times 0.20\,\text{m\,s}^{-1} = 80\,000\,\text{W} = 80\,\text{kW}$.

5

The answer is option **B**.

This problem can be solved by considering the situation when the object is falling at an acceleration of $0.5g$ with velocity v_0.

Weight of object $= mg$

Drag force acting on object $F = kv_0{}^n$

Resultant force on object downwards $= mg - kv_0{}^n = ma = 0.5mg$

Rearranging:

$$\frac{1}{2}mg = kv_0{}^n$$

$$k = \frac{mg}{2v_0{}^n}$$

Now consider the object falling at terminal speed v_T:

Drag force $=$ weight, so:

$$kv_T{}^n = mg$$

$$\frac{mg}{2v_0{}^n}v_T{}^n = mg$$

$$2v_0{}^n = v_T{}^n$$

Raising both sides to the power ($1/n$):

$$2^{(1/n)}v_0 = v_T$$

6

The answer is option **E**.

This problem can be solved by considering the ratio of the forces on and extensions of the springs.

The weight of each mass is $0.10\,\text{kg} \times 10\,\text{N kg}^{-1} = 1.0\,\text{N}$

The weight of the springs can be ignored because their masses are negligible.

The force on the upper spring is 2.0 N, and the force on the lower spring is 1.0 N.

As they are subjected to different forces, the two springs will have different extensions.

Force, *F*, and extension, x, are related by $F = kx$ and the spring constant, k, is the same for both springs.

Therefore, since the ratio of the forces on the upper and lower springs is 2 : 1, their extensions must also be in the ratio 2 : 1

The sum of the extensions of the two springs is $30.0\,\text{cm} - (2 \times 12.0\,\text{cm}) = 6.0\,\text{cm}$.

Splitting this in the ratio 2 : 1 gives 4.0 cm : 2.0 cm for the extensions of the upper and lower springs respectively.

The spring constant k can be calculated by considering either of the springs:

Upper spring: Lower spring:

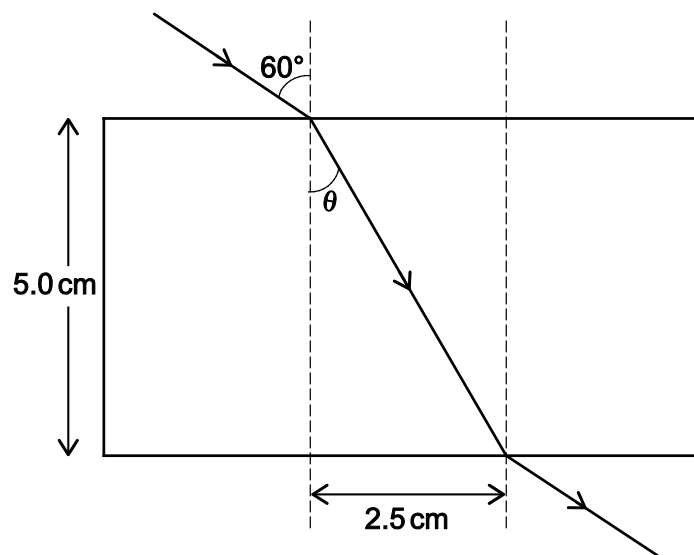$$k = \frac{F}{x} = \frac{2.0\,\text{N}}{4.0\,\text{cm}} = 0.50\,\text{N cm}^{-1}$$ $$k = \frac{F}{x} = \frac{1.0\,\text{N}}{2.0\,\text{cm}} = 0.50\,\text{N cm}^{-1}$$

7

The answer is option **H**.

This problem can be solved by using trigonometry to find the angle θ (shown in the diagram) and then using the law of refraction to find the refractive index n of the block.

Using Pythagoras, $\quad \sin\theta = \dfrac{2.5}{\sqrt{2.5^2 + 5.0^2}} = \dfrac{2.5}{\sqrt{\frac{25}{4} + 25}} = \dfrac{2.5}{\sqrt{\frac{125}{4}}} = \dfrac{2.5}{\sqrt{\frac{5 \times 5 \times 5}{4}}} = \dfrac{2.5}{2.5\sqrt{5}} = \dfrac{1}{\sqrt{5}}$

Since $\sin 60° = \dfrac{\sqrt{3}}{2}$

$$n = \frac{\sin 60°}{\sin\theta} = \frac{\sqrt{3}/2}{1/\sqrt{5}} = \frac{\sqrt{3}\sqrt{5}}{2} = \frac{\sqrt{15}}{2}$$

8

The answer is option **B**.

This problem can be solved by considering the displacements of point mass.

Assume that positive vector quantities are in the direction from P towards Q time $t = 0$.

The point of zero displacement is taken to be the position of P at time $t = 0$.

At time t, mass P has displacement

$$s = \frac{1}{2}at^2$$

$$= \frac{1}{2} \times 6 \times t^2$$

$$= 3t^2$$

The initial displacement of Q is +60 m.

At time t, mass Q has displacement

$$s = 60 + ut + \frac{1}{2}at^2$$

$$= 60 + (-14t) + \frac{1}{2} \times 2t^2$$

$$= 60 - 14t + t^2$$

Masses P and Q meet when they have the same displacement at the same time, so

$$3t^2 = 60 - 14t + t^2$$

$$2t^2 + 14t - 60 = 0$$
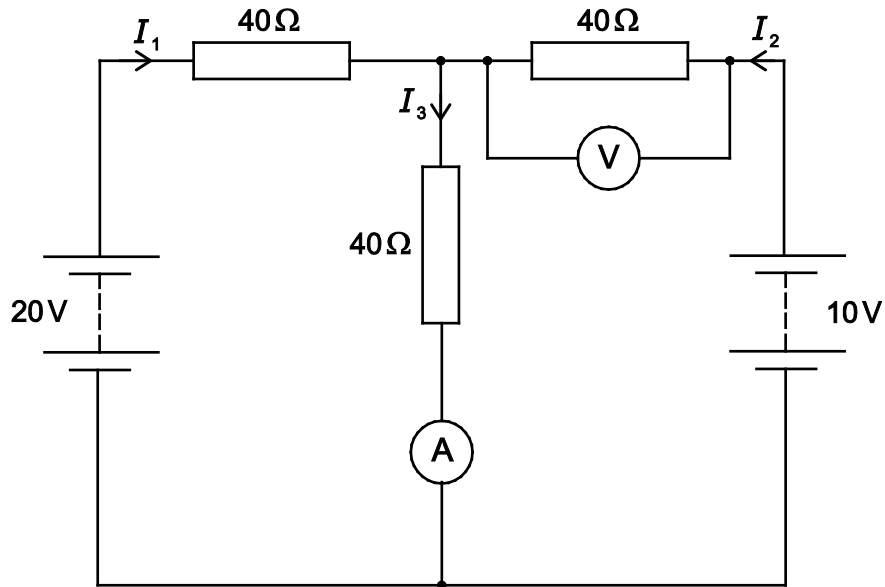
$$t^2 + 7t - 30 = 0$$

$$(t - 3)(t + 10) = 0$$

Therefore P and Q will meet when $t - 3 = 0$, so $t = 3.0$ s.

9

The answer is option **A**.

This problem can be solved using Kirchhoff's laws and solving the resulting simultaneous equations.

Label currents I_1, I_2 and I_3 as shown in the diagram.

Using Kirchhoff's laws:

$$I_3 = I_1 + I_2 \qquad (1)$$

$$20 = 40I_1 + 40I_3 \qquad (2)$$

$$10 = 40I_2 + 40I_3 \qquad (3)$$

From (1) $I_1 = I_3 - I_2$, so substitute for I_1 into (2):

$$20 = 80I_3 - 40I_2$$

Add this to (3):

$$30 = 120I_3$$

giving the ammeter reading I_3 :

$$I_3 = \frac{30}{120} = 0.25\,\text{A}$$

Substitute for I_3 into (3):

$$10 = 40I_2 + 10$$

$$I_2 = 0\,\text{A}$$

The voltmeter is therefore connected across a resistor that has no current, so the voltage across it is zero, and the voltmeter reading is $0\,\text{V}$.

10.

The answer is option **E**.

This problem can be solved by considering both the hydrostatic pressure and the pressure due to the force of the water falling.

The water falls 45 m. Its velocity just before hitting the rock can be calculated from conservation of energy:

$$\text{change in kinetic energy} = \text{change in gravitational potential energy}$$

$$\tfrac{1}{2}mv^2 = mgh$$

$$v = \sqrt{2gh}$$

$$= \sqrt{2 \times 10 \times 45}$$

$$= \sqrt{900}$$

$$= 30\,\text{m}\,\text{s}^{-1}$$

The pressure on the rock surface arises from two things. Firstly, the hydrostatic pressure from water resting on the surface, and secondly the pressure exerted on the surface as the water stops, equal to its rate of change of momentum divided by the area of the rock.

hydrostatic pressure $P_1 = \rho g h = 1000 \times 10 \times 0.050 = 500\,\text{Pa}$

pressure $P_2 = \dfrac{F}{A} = \dfrac{\Delta(mv)}{A\Delta t} = \dfrac{40 \times 30}{2.0} = 600\,\text{Pa}$

Total pressure exerted on the rock is $P = P_1 + P_2 = 500 + 600 = 1100\,\text{Pa}$.

CHEMISTRY

11

The answer is option **D**.

The heat required to warm the copper container and that required to warm the water are calculated separately using the expression $Q = mc\Delta T$

$$\text{Copper:} \qquad Q_1 = 500 \times 0.4 \times 60 = 12\,000\,\text{J} = 12\,\text{kJ}$$

$$\text{Water:} \qquad Q_2 = 400 \times 4 \times 60 = 96\,000\,\text{J} = 96\,\text{kJ}$$

Total heat transfer $= Q_1 + Q_2 = 12 + 96 = 108\,\text{kJ}$

This is only 20% of the heat released by burning the methane.

So, total heat released from burning $= 108 \times \dfrac{100}{20} = 540\,\text{kJ}$

Number of moles of methane burned to release this amount of heat $= \dfrac{540}{900} = 0.6\,\text{mol}$

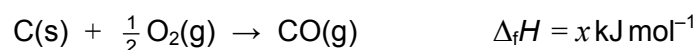Mass of methane $= 0.6 \times 16 = 9.60\,\text{g}$

The answer is option **A**.

$\Delta_r H$ is the enthalpy of reaction and $\Delta_f H$ is the enthalpy of formation.

Deduce reaction equation: $HgC_2N_2O_2 \rightarrow Hg + N_2 + 2CO$ $\Delta_r H = -606\,kJ\,mol^{-1}$

Deduce equation for enthalpy of formation of mercury(II) fulminate:

$$Hg(l) + 2C(s) + N_2(g) + O_2(g) \rightarrow HgC_2N_2O_2(s) \qquad \Delta_f H = +386\,kJ\,mol^{-1}$$

Deduce equation for enthalpy of formation of carbon monoxide:

$$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta_f H = x\,kJ\,mol^{-1}$$

Construct a Hess cycle:

$$HgC_2N_2O_2(s) \quad \xrightarrow{\;-606\;} \quad Hg(l) + N_2(g) + 2CO(g)$$

$$+386 \qquad\qquad 2x$$

$$Hg(l) + N_2(g) + 2C(s) + O_2(g)$$
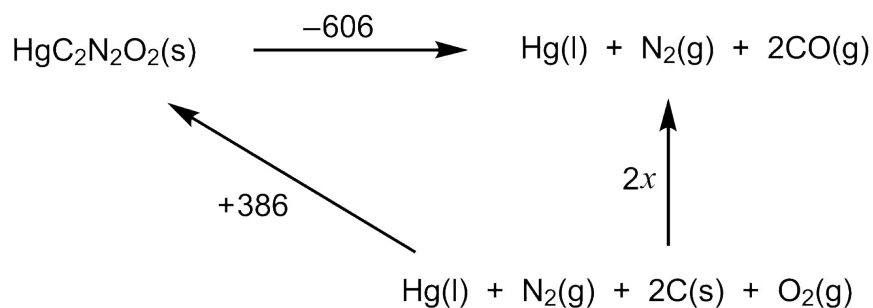
$2x = (+386) + (-606) = -220$

$x = -110\,kJ\,mol^{-1}$

13

The answer is option **B**.

The hydrocarbon contains 14.3% by mass of H, so must contain 85.7% by mass of C.

The empirical formula of X is found by considering the ratio $C:H$ which is $\dfrac{85.7}{12}:\dfrac{14.3}{1}$, cancelling to 2:1 by approximation.

Therefore the empirical formula is CH_2.

The mass spectrum shows the molecular ion peak at $m/z = 84$, so $M_r = 84$.

The molecular mass of cyclobutane (C_4H_8) is 56. This corresponds to the highest intensity peak, but that does not correspond to the molecular ion.
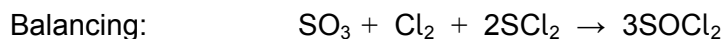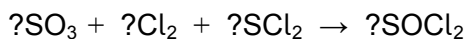
Molecular formula of X is therefore: C_6H_{12}

X does not react with bromine, so it is not an alkene. X cannot be hex-2-ene.

X must be a cycloalkane with 6 C atoms, such as cyclohexane.

14

The answer is option **E**.

From the information provided in the question the formulae in the chemical equation can be deduced to be:

$$?SO_3 + ?Cl_2 + ?SCl_2 \rightarrow ?SOCl_2$$

Balancing: $$SO_3 + Cl_2 + 2SCl_2 \rightarrow 3SOCl_2$$

Number of moles Cl_2 gas $= \dfrac{2}{24} = \dfrac{1}{12}$

Mole ratio $Cl_2 : SOCl_2$ $= 1 : 3$

Number of moles of $SOCl_2$ $= \dfrac{1}{12} \times 3 = 0.25\,mol$

$SOCl_2$ is collected in water, where it reacts. It produces HCl, which will dissolve to form hydrochloric acid, and another gaseous product, which can be deduced to be sulfur dioxide:

$$SOCl_2 + H_2O \rightarrow 2HCl + SO_2$$
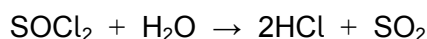
Mole ratio $SOCl_2 : HCl$ $= 1 : 2$

Number of moles of HCl $= 0.25 \times 2 = 0.50\,mol$

Concentration of HCl $= \dfrac{\text{number of moles}}{\text{volume}} = \dfrac{0.50}{\left(\dfrac{200}{1000}\right)} = 2.50\,mol\,dm^{-3}$

15

The answer is option **A**.

The oxidation state of silver in Tollens' reagent is +1, as NH_3 is a neutral species and the nitrate anion has a charge of -1.

It acts as a reducing agent as shown by the half-equation: $Ag^+(aq) + e^- \rightarrow Ag(s)$

Combining this with the organic oxidation half-equation shows that the overall reaction has the stoichiometry:

$$2Ag^+(aq) + RCHO + H_2O \rightarrow 2Ag(s) + RCOOH + 2H^+$$
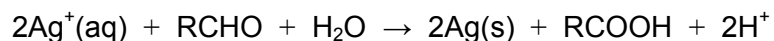
The internal surface area of the beaker is the area of the circular base added to the curved sides.

Surface area to be coated $= \pi r^2 + 2\pi rh = 25\pi + 100\pi = 125\pi \, cm^2$

Volume of silver required $=$ surface area $\times$ thickness $= 125\pi \, cm^2 \times 0.01 \, cm = 1.25\pi \, cm^3$

Mass of silver required in g $=$ volume $\times$ density $= 1.25\pi \, cm^3 \times 10.5 \, g \, cm^{-3}$

Number of moles of Ag(s) required $= \dfrac{\text{mass in g}}{A_r(Ag)} = \dfrac{10.5 \times 1.25 \times \pi}{108}$

So, the number of moles of aldehyde required $= \dfrac{1}{2} \times \dfrac{10.5 \times 1.25 \times \pi}{108}$

16

The answer is option **C**.

The reaction between hydrogen and oxygen can be written as: $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

The bond enthalpy of O_2 is not given: let it be x

When using bond enthalpies, the overall enthalpy change is equal to the energy released in forming bonds minus the energy absorbed in breaking bonds.

(All of the following calculations are in $kJ\,mol^{-1}$)

Enthalpy change in breaking H_2 and O_2 bonds $= 436 + \dfrac{x}{2}$

Enthalpy change in forming two $O-H$ bonds in $H_2O = -2 \times 464 = -928$

Enthalpy change when hydrogen, H_2 is burned $= -492 + \dfrac{x}{2}$

Enthalpy change in breaking D_2 and O_2 bonds $= 443 + \dfrac{x}{2}$

Enthalpy change in forming two $O-D$ bonds in $D_2O = -2 \times 471 = -942$

Enthalpy change when hydrogen, D_2 is burned $= -499 + \dfrac{x}{2}$

More energy is released when D_2 is burned. Statement 1 is not correct.

From the information given:

$$\frac{[H^+][OH^-]}{[H_2O]} > \frac{[D^+][OD^-]}{[D_2O]}$$

Therefore, H_2O dissociates more readily than D_2O as the dissociation products are in the numerators of the equilibrium constant expressions. This means that there will be a higher concentration of H^+ ions present in the H_2O equilibrium than there will be D^+ ions in the D_2O equilibrium. Hence, H_2O is more acidic. Statement 2 is correct.

The boiling points of simple molecular substances are dependent on the attraction between the molecules, not the bond enthalpy. In these molecules the $H-H$, $D-D$, $O-H$ and $O-D$ bonds do not break during physical changes. Statement 3 is not correct.

17

The answer is option **E**.

Putting the known coefficients into the equation:

$$As_2O_3(s) + 6Zn(s) + H^+(aq) \rightarrow 6Zn^{2+}(aq) + 2X(g) + H_2O(l)$$
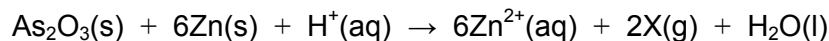
Six zinc atoms each increase their oxidation state by 2 in being oxidised to zinc ions. This gives a total increase in oxidation state of 12.

To balance this, the two arsenics in As_2O_3 must collectively reduce their oxidation states by 12 (i.e. each arsenic in As_2O_3 must reduce its oxidation state by 6).

The oxidation state of arsenic in As_2O_3 is +3 (because the oxidation state of the oxygen is –2). Hence each of the two arsenics in X must have an oxidation state of –3.

The only possible arsenic-containing product in this reaction that gives arsenic an oxidation state of –3 is AsH_3.

The balanced equation for the reaction is therefore:

$$As_2O_3(s) + 6Zn(s) + 12H^+(aq) \rightarrow 6Zn^{2+}(aq) + 2AsH_3(g) + 3H_2O(l)$$
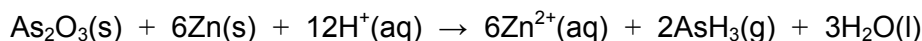
The M_r of As_2O_3 is 198 and the M_r of AsH_3 is 78.

From the stoichiometry of the reaction, 198 g of As_2O_3 would produce 156 g of AsH_3.

Hence, 1.98 g of As_2O_3 would produce 1.56 g of AsH_3.

18

The answer is option **E**.

Compound P must have a C=C bond somewhere in its structure, and Q is a bromoalkane.

Alcohols are formed when bromoalkanes undergo substitution reactions with aqueous sodium hydroxide.

When completely oxidised by acidified potassium dichromate(VI), primary alcohols form carboxylic acids which do react with aqueous sodium carbonate.

Secondary alcohols are oxidised to ketones which do not react with aqueous sodium carbonate and tertiary alcohols cannot be oxidised by acidified potassium dichromate(VI). Therefore R must be a secondary alcohol.

Pent-1-ene is incorrect as it would form 2-bromopentane as the only major product with HBr, which would then form pentan-2-ol. This would be dehydrated to form pent-2-ene as the other alkene, S. This does have stereoisomers.

Pent-2-ene is incorrect as there would be two products in significant quantity formed in the reaction with HBr: 2-bromopentane and 3-bromopentane (both formed from secondary carbocations).

The correct answer must therefore be one of the branched alkenes. If P were either 2-methylbut-1-ene or 2-methylbut-2-ene, because the double bond is adjacent to the branch in the chain, a tertiary bromoalkane would be formed as the major product. After the substitution reaction, this bromoalkane would become a tertiary alcohol, which cannot be oxidised by acidified potassium dichromate(VI).

3-methylbut-1-ene must therefore be the correct answer. This alkene would firstly form 2-bromo-3-methylbutane as the only major product with HBr and then 2-methylbutan-2-ol. This alcohol would be dehydrated to form 2-methylbut-2-ene as alkene S, which has two methyl groups attached to one end of the carbon double bond, and therefore does not have stereoisomers.

19
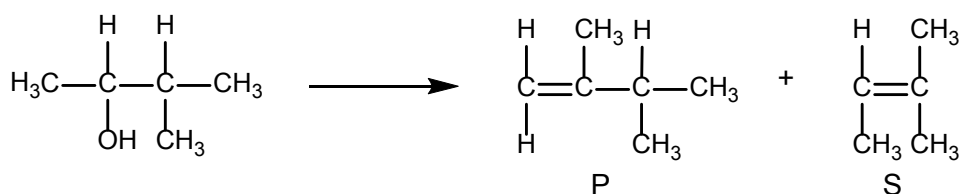
The answer is option **G**.

Both bromine and fluorine are in Group 17. F is more electronegative than Br and can form multiple bonds.

Bromine contributes 7 outer electrons to bonding, and the three F atoms contribute one further electron each. So there are 10 outer electrons around the Br centre, i.e. 5 pairs of electron density.

The structure is therefore based on a trigonal bipyramid. As there are only three bonds, two of these regions of electron density are lone pairs. There are several possible shapes that could form according to VSEPR, but only T-shaped would be faithful to the symmetry if only two bond lengths are equal and the third is not.
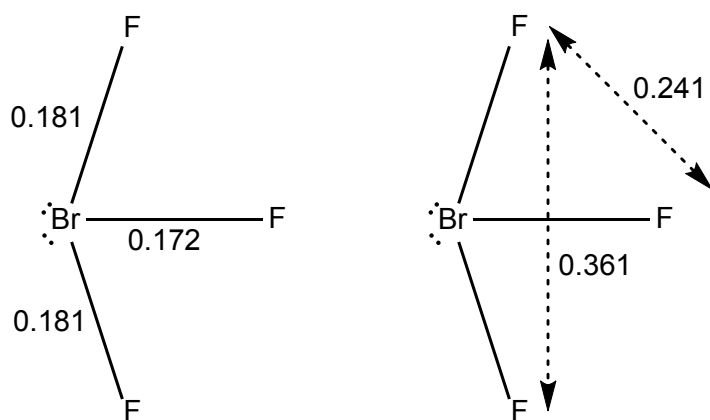
Finding a right-angled triangle using appropriate distances, and using the inverse sine function $(\sin^{-1})$, gives the bond angle as $\sin^{-1}\left(\dfrac{0.1805}{0.181}\right)$ $(= 86°)$
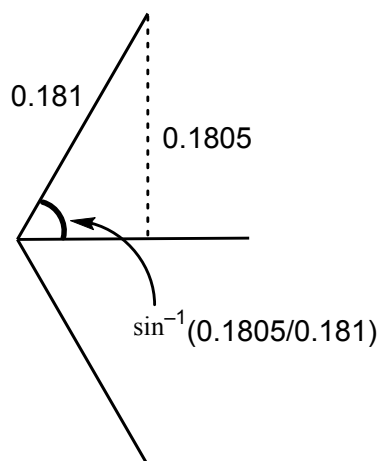
The answer is option **C**.

	CH$_3$COOH	+	CH$_3$CH$_2$OH	⇌	CH$_3$COOCH$_2$CH$_3$	+	H$_2$O
mass at the start	120		92		0		18
M_r	60		46		88		18
number of moles at the start	2		2		0		1
number of moles at equilibrium	$2-x$		$2-x$		x		$1+x$

The equilibrium constant is: $\quad K_c = \dfrac{[CH_3COOCH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2OH]}$

Substituting in the number of moles: $\quad K_c = \dfrac{(x)(1+x)}{(2-x)(2-x)} = 2$

Rearranging: $\qquad\qquad x^2 + x \ = \ 2(x^2 - 4x + 4)$

$\qquad\qquad\qquad\qquad x^2 + x \ = \ 2x^2 - 8x + 8$

$\qquad\qquad\qquad\qquad x^2 - 9x + 8 \ = \ 0$

Using the quadratic formula: $\quad x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \dfrac{-9 \pm \sqrt{9^2 - 32}}{2}$

$\qquad$ or by factorising: $\qquad (x-8)(x-1) = 0$

$\qquad\qquad\qquad\qquad x \ = \ 8 \ \text{ or } \ 1$

A value of 8 is impossible because that would require '−6 mol' of reactants.

At equilibrium there would be just one mole of ester, which has a mass of 88 g.

BIOLOGY

21

The answer is option **E**.

Statement 1 is correct. From the equation:

$$\left(\frac{1 - \frac{1}{R_0}}{\text{effectiveness of the vaccine}} \right) \times 100$$

R_0 is the average number of people who catch the disease from one infected person. If R_0 increases, then $1 - \frac{1}{R_0}$ will also increase. If the effectiveness of the vaccine remains the same, then the number of people who need to be vaccinated must increase to prevent the spread of disease.

Statement 2 is correct:

$$1 - \frac{1}{3} = \frac{2}{3} = 0.\dot{6}$$

$$\frac{0.6666}{0.9} = 0.741, \text{ or just over 74\%}$$

Statement 3 is not correct as whilst antibiotics can be effective against bacteria they are not components of a vaccine.

22

The answer is option **A**.

The percentage change in mass is:

$$\frac{\text{change in mass}}{\text{initial mass}} \times 100$$

In $0.6 \, \text{mol dm}^{-3}$ sugar solution, the potato piece reduces in mass from $3.93 \, \text{g}$ to $2.62 \, \text{g}$. This is a change of $-1.31 \, \text{g}$. The initial mass is $3.93 \, \text{g}$.

So, the correct calculation is:

$$\frac{-1.31}{3.93} \times 100 = 33\% \text{ decrease}$$

The concentration of sugar solution that was most similar to the concentration of water molecules in the cytoplasm will be the one which causes a minimum change in mass of the potato piece. This is $0.2 \, \text{mol dm}^{-3}$.

23

The answer is option **E**.

Using data from the bar chart, there are 42 mammals in the owl's diet of which 6 are mice:

$$\frac{6}{42} \times 100 = 14.3\%$$

The change in the population (r) can be calculated by adding together the births (b) and immigration (i), adding together the deaths (d) and emigration (e), then subtracting the second figure from the first, as in the equation:

$$r = (b + i) - (d + e)$$
$$(242 + 11) - (207 + 21) = 25$$

However, this figure is for 2 weeks. The mean change per week is $25 \div 2 = 12.5$

Although this figure shows there is an increase in the mouse population, it is not possible to make a judgement on whether the owl's diet would be likely or unlikely to show an increase in mice, because there is no data available about what is happening to the populations of the other organisms in the owl's diet. The only sound conclusion is that there is insufficient evidence to know the effect on the owl's diet.

24

The answer is option **E**.

The clear circular area on each plate can be calculated using the formula: area $= \pi r^2$

The radius is obtained by dividing the diameter by 2. The diameter is shown in mm.

The radius for the clear area for plate Q is 10 mm, so the area is 100π mm^2.

For the agar plate the diameter is in cm so needs to be converted into mm by multiplying by 10. The diameter is 10 cm so the radius is 5 cm, or 50 mm. The area of the plate is $50 \times 50 \times \pi = 2500\pi$ mm^2.

Therefore the area of the pathogen is $2500\pi - 100\pi = 2400\pi$ mm^2.

The most effective antibiotic is P as it has the largest clear area.

25

The answer is option **H**.

Of the 100 units of solar energy reaching the leaf, 50 units are the wrong wavelength, 5 units are transmitted (pass) through the leaf without hitting a chloroplast and 5 units are reflected off the leaf. So, 60% of the solar energy reaching the leaf is **not** absorbed by chloroplasts. Statement 1 is correct.

The total energy absorbed by the chloroplasts is 40 units, of which 9 units are used in production of glucose.

$\frac{9}{40} \times 100 = 22.5\%$. Statement 2 is correct.

The chloroplasts harness 9 units of energy and convert it into glucose. However, 3.7 units are lost by the mitochondria in respiration. The remainder $(9 - 3.7)$ is 5.3 units, which is the maximum available to the primary consumer. Statement 3 is correct.

26

The answer is option **H**.

Parents 1 and 2 have yellow fur but they have produced offspring with black fur so the yellow fur allele must be dominant.

The two individuals with black fur must each have two copies of the black fur allele as it is recessive. All of the live individuals who have yellow fur (9 of them) must be heterozygous, as homozygous dominant individuals die before birth. This means that there are 9 more copies of the black fur allele present. This is a total of $4 + 9 = 13$ black fur alleles.

A cross between 5 and 6 is a cross between two heterozygous individuals as they are both alive and have yellow fur. The expected ratio of phenotypes from this cross will be one homozygous dominant who will die before birth and so cannot be counted in the live offspring, two heterozygous yellow fur individuals, and one homozygous recessive individual with black fur. This gives a phenotype ratio of $2:1$.

27

The answer is option **F**.

In order to calculate the volume of water lost, we use the volume of the tubing, which is a cylinder:

$$\text{volume of cylinder} = \pi r^2 h$$

For P, this is $\pi \times 0.3^2 \times 90 = \pi \times 0.09 \times 90 = 8.10\pi$

For Q, this is $\pi \times 0.5^2 \times 33 = \pi \times 0.25 \times 33 = 8.25\pi$

For R, this is $\pi \times 0.6^2 \times 25 = \pi \times 0.36 \times 25 = 9.00\pi$

Therefore, the order from most to least is: R, Q, P.

The information provided does not specify anything about controlling variables, so it is possible that R was in a humid environment. However, the loss of water (transpiration) under these conditions is expected to be very low, not the most water lost.

There is also no indication that the leaf area was the same in all three experiments, nor that other variables were controlled.

Therefore, it is only possible to say there is insufficient data to explain the results.

28

The answer is option **G**.

The process of increasing the variation between the two groups of maize grains is not a natural one, but carried out in an experiment artificially. Statement 1 is not correct.

The graph shows that the percentage oil content in the high oil content grains was 5% at the start of the experiment. This increased to 14% after 50 generations.

Percentage change is:

$$\frac{\text{change in percentage oil content}}{\text{oil content at start}} \times 100\%$$

$$= \frac{(14 - 5)}{5} \times 100\%$$

$$= 180\%$$

Statement 2 is correct.

The maize grains had a mean mass of 0.4 g. At the start of the experiment for the high oil content grains, 5% of this mass was oil:

$$\frac{5}{100} \times 0.4 = 0.02\,\text{g}$$

After fifty generations, 14% of each grain was oil:

$$\frac{14}{100} \times 0.4 = 0.056\,\text{g}$$

The difference is $0.056 - 0.02 = 0.036\,\text{g}$

Statement 3 is correct.

29

The answer is option **C**.

The gaseous product of photosynthesis is oxygen. Statement 1 is not correct.

Any of the points where the distance doubles can be used to test Statement 2. Several intervals should be checked to confirm the relationship.

Between 10 cm and 50 cm, the relationship between the rate of gas production (photosynthesis) and distance from the light source matches the inverse square relationship between distance from the light source and light intensity, e.g. as the distance doubles (from 10 cm to 20 cm) the light intensity will decrease to:

$$\left(\frac{1}{d^2}\right) = \left(\frac{1}{2^2}\right) = \frac{1}{4} \text{ of the original value}$$

This matches the decrease in photosynthesis, which decreases by a factor of 4, from 80 to 20 bubbles.

Similarly, as the distance goes up from 10 cm to 40 cm the light intensity will decrease to $\left(\frac{1}{4^2}\right) = \frac{1}{16}$ of the original value, again matching the decrease in photosynthesis, from 80 to 5 bubbles.

Therefore, statement 2 is correct.

As the pondweed is moved closer than 10 cm to the light source, light intensity will be increasing but the rate of photosynthesis does not increase. Therefore, some factor other than light intensity must be rate limiting at 5 cm. Statement 3 is not correct.

30

The answer is option **E**.

Statement 1 is correct.

$\frac{3}{4}$ of the alleles are the dominant B allele, so the probabilities of each genotype are:

	B ¾	b ¼
B ¾	$\frac{9}{16}$	$\frac{3}{16}$
b ¼	$\frac{3}{16}$	$\frac{1}{16}$

Flour beetles with genotypes BB and Bb will have black eyes.

The proportion of black eye beetles will be: $\frac{9}{16} + \frac{3}{16} + \frac{3}{16} = \frac{15}{16}$

Therefore the number of beetles with black eyes in the population is: $\frac{15}{16} \times 1600 = 1500$

Statement 2 is correct. The body cells each have two copies of chromosome 5, and this means they are diploid.

Statement 3 is not correct.

For this population of beetles, using the probabilities in the table for Statement 1:

homozygous black eye (BB) $= \frac{9}{16}$

heterozygous black eye (Bb) $= \frac{3}{16} + \frac{3}{16}$

red eye (bb) $= \frac{1}{16}$

Therefore the ratio of homozygous black eye beetles to heterozygous black eye beetles to red eye beetles is $9 : 6 : 1$