Worked Solutions for NSAA Past Papers

NSAA Section 2 2016 - Question 1

Question 1

a) A narrow beam of molecules with a range of different speeds passes through a molecular velocity selector.

The selector comprises two discs rotating in the same direction at the same frequency of rotation f on a common axis in an evacuated container.

The selector allows molecules with particular speeds to pass through.

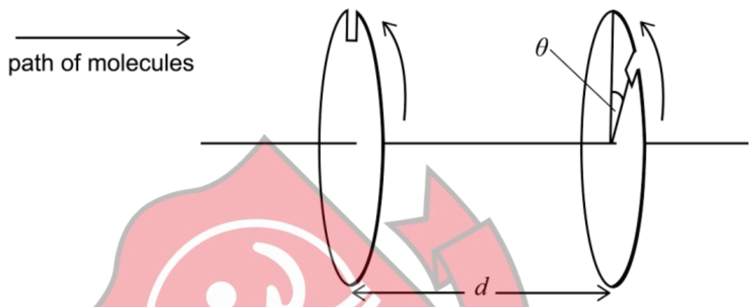


Fig. 1.1

The speeds of the molecules, v, entering the selector vary over a very broad range. The molecules can pass through a very narrow slit on each of the two discs, as shown in Fig. 1.1. The slit on the right-hand disc is displaced by angle θ relative to the slit on the left-hand disc. The horizontal separation of the discs is d.

(The effects of gravity may be ignored and the speed of a molecule within the container remains constant.)

(i) For $f = 160$ revolutions s^{-1}, how long does it take for the discs to rotate through 1.0°? **[2 marks]**

NSAA 2016 Section 2 - Question 1 a(i) - Worked Solution

Frequency = 160 revolutions per second Therefore, rotation in 1 second = 360 degrees x 160 = 57600 degrees So, for 1 degree, time is 1/57600 = 1.7 x 10^-5 s

(ii) If $\theta = 30.0°$, $d = 24.0$ cm and $f = 160$ revolutions s^{-1}, what is the highest speed of a molecule that will pass through both slits? **[3 marks]**

NSAA 2016 Section 2 - Question 1 a(ii) - Worked Solution

The time of flight of the molecule must be equal to the time taken for the disc to rotate by theta degrees. Therefore, for theta = 30 degrees, time taken = 30 x 1.7 x10^-5 = 5.2 x 10^-4s. Speed = distance/ time, so for the distance being 24cm, v = 0.24/5.2 x 10^-4 = 460.8m/s

(iii) When the speeds of the molecules are measured after they have passed through the two narrow slits, it is found that other molecular speeds are present. Explain why there is more than one speed in the outgoing beam. **[3 marks]**

NSAA 2016 Section 2 - Question 1 a(iii) - Worked Solution

Words to the effect of: the molecules may pass through the second slit after any number of rotations. Slower moving molecules may pass through the second slit after it has rotated by theta + (n x 360 degrees). Therefore, there will be a discrete set of speeds at which molecules may pass through the second slit.

(iv) For the arrangement described in **(ii)**, calculate the molecular speed, closest to your value in **(ii)**, that will pass through both slits. **[3 marks]**

NSAA 2016 Section 2 - Question 1 a(iv) - Worked Solution

For an extra rotation, i.e. the second disc has rotated 360 + 30 = 390 degrees.
The time taken for the molecule to travel will then be 390/ (360 x 160) = 6.77 x 10 ^-3s
Distance is still 24cm so v = 0.24/6.77x10^-3 = 35.4m/s

(v) Each slit has an angular width of 0.3° either side of its centre, with the centres of the slits being θ apart. What is the range of speeds ($v_{max} - v_{min}$) for the set of molecules referred to in **(ii)** that pass through both slits? **[3 marks]**

NSAA 2016 Section 2 - Question 1 a(v) - Worked Solution

Angular width of 0.3 degrees either side on both slits means that the maximum speed comes from a molecule which passes through the second slit when theta = 29.4 degrees, and the minimum from theta = 30.6 degrees.

Therefore vmax = 0.24 x 160 x 360/29.4 = 470m/s

And vmin = 0.24 x 160 x 360/30.6 = 452m/s

Range = 470-452 = 18m/s

b) A particle of mass m falls through height h on to a thin disc rotating at a rate f revolutions s^{-1}. The particle will just fit through a hole in the rotating disc (Fig. 1.2).

(The effects of air resistance may be ignored; take the acceleration due to gravity as $9.81\,m\,s^{-2}$.)

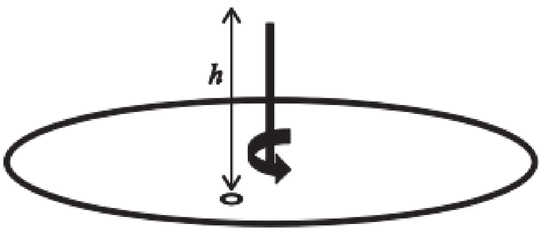


Fig. 1.2

(i) The disc is rotating at frequency f revolutions s^{-1} when the particle is released from rest. Working in degrees, write down an expression for the angle θ through which the disc will have turned by the time the particle reaches it. **[3 marks]**

NSAA 2016 Section 2 - Question 1 b(i) - Worked Solution

The time passed will be equal to the angle theta/ (360 x f), and also equal to sqrt(2h/g).
Therefore, theta = 360 x f x sqrt(2h/g)

(ii) If f = 20 revolutions s^{-1} and a particle, initially at rest, is released at the moment that the hole is vertically below it, what is the minimum height (greater than zero) from which the particle can be dropped so that it will pass through the hole? **[2 marks]**

NSAA 2016 Section 2 - Question 1 b(ii) - Worked Solution

As above, t = sqrt(2h/g) (from s = ut + 0.5at^2, where u = 0, s = h, a = g).
t also equals 1/frequency = 1/20, therefore sqrt(2h/g) = 1/20, so h = 1.23 x 10^-2m

(iii) An identical disc with a similar hole is fixed to the same axis, but at a distance $h' = 0.15\,\text{m}$ below it. The two holes are aligned. When the particle is released from rest at a height $h = 0.10\,\text{m}$ above the top disc, it is able to fall through both holes in succession. What is the minimum frequency of rotation (greater than zero) of both discs which will allow this to occur? **[6 marks]**

NSAA 2016 Section 2 - Question 1 b(iii) - Worked Solution

There are quite a few ways to answer this question, including algebraically and graphically. Here is one way:

At the top disc, the speed of the particle squared is 2gh.

If the time taken to travel between the two discs (distance h') is t',

h' = vt' + 0.5gt'^2

Substitute for v to give the quadratic:
h' = sqrt(2gh) t' + 0.5gt'^2

Rearrange giving: t'^2 + sqrt (8h/g) t' – 2h'/g = 0

Solve using the quadratic formula to give t' = (-1/sqrt9.81)(sqrt(2 x 0.1) minus/plus sqrt(2 x (0.1 + 0.15)))

Only one answer physically possible gives t' = 0.083s and f = 1/t' = 12 rotations/s

NSAA Section 2 2016 - Question 2

Question 2

a) Calculate the readings shown on the voltmeter and on ammeters A_1 and A_2 in the circuits shown in Fig. 2.1 **(i)** and **(ii)**.

(You may assume that the ammeters and voltmeters are ideal and that the cells have negligible internal resistance.)

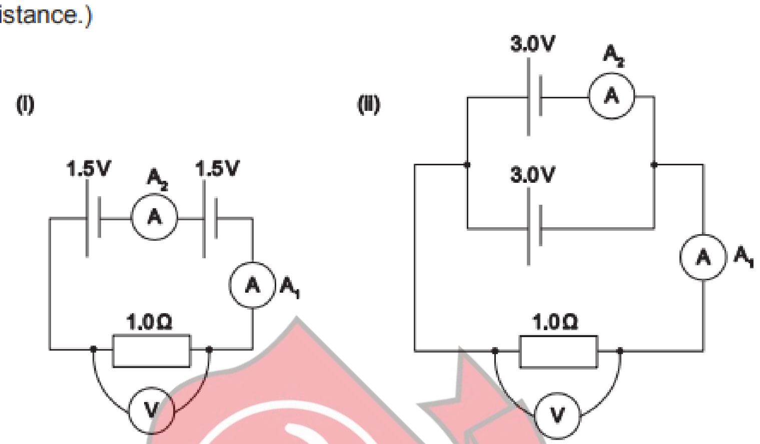


Fig. 2.1 **[5 marks]**

NSAA 2016 Section 2 - Question 2 (a) - Worked Solution

Circuit (i):

Two 1.5V cells in series = 1.5 + 1.5 = 3.0V total in circuit

The two currents are identical, so using V = IR:

I = V/R = 3.0/1.0 = 3.0A

Circuit (ii):

Total voltage in the circuit = two 3.0V cells in parallel gives 3.0V total

A1 is as in circuit (i), as this ammeter is in series with the other components: V/R = 3.0/1.0 = 3.0A

A2 is different as current splits at junctions. The resistance of each side of the parallel part of the circuit is the same, therefore the current A1 splits equally so A2 = A1/2 = 1.5A

b) In a more realistic model, the 1.5 V cell has an internal resistance of 0.10 Ω and the 3.0 V cell also has an internal resistance of 0.10 Ω. Calculate the new readings on the voltmeter and on the ammeters for the circuits shown in Fig. 2.1 **(i)** and **(ii)**. **[5 marks]**

NSAA 2016 Section 2 - Question 2 (b) - Worked Solution

Adding internal resistance means that a cell can be treated as having a small resistor in series with it.

For circuit (i):

Total resistance in the circuit now = 1.0 + 2(0.1) = 1.2 Ohms
EMF = 3.0V, so A1 = A2 = EMF/Rtotal = 3.0/1.2 = 2.5A
Voltage on voltmeter is no longer 3.0V due to the added resistance so V = IR = 2.5 x 1.0 = 2.5V

For circuit (ii):

V = (E – Ir) = IR
So, EMF = I(R + r/2) so I = A1 = EMF/(R + r/2) = 2.86A (EMF = 3.0V as before)

V = IR = 2.86 x 1.0 = 2.9V
A2 = A1/2 = 1.43V

c) The 1.5 V and 3.0 V cells each store the same amount of energy. In which of the four arrangements described in **a)(i)** and **(ii)** and **b)(i)** and **(ii)** do the cells take the longest time to transfer all their energy into heat? Explain your reasoning. **[2 marks]**

NSAA 2016 Section 2 - Question 2 (c) - Worked Solution

The cells in b(i) will last the longest if all of the cells have the same amount of energy. Rate of energy provided by each cell in b(i) = P = EI/2 = 3.75W. a(i) and a(ii) have P = 4.50W and b(ii) has P = 4.29W. Therefore, smallest rate of transfer = smallest power = b(i).

d) A solar cell can be modelled as an ideal cell of 0.50 V in series with an internal resistor of 0.10 Ω. We want to operate a fan that consumes 0.96 W of power and requires a potential difference of 2.4 V. There are 10 identical solar cells available and all must be used. They are arranged as n identical parallel sections with each section consisting of N cells in series. How must they be arranged in the circuit, and what is the current in each solar cell? In both cases explain your reasoning. **[4 marks]**

NSAA 2016 Section 2 - Question 2 (d) - Worked Solution

2d) 5 cells in 2 parallel sections ($n = 2$, $N = 5$) [1 mark]
$I = 0.2A$ [1 mark]

Method 1 (guesswork and reasoning):
Current required by fan is given by $P = VI \rightarrow I = 0.4A$ [1 mark]

Potential difference required is 2.4V which is at least 5 solar cells in series [1 mark]

OR

Method 2 (simultaneous equations):
$V = N(\epsilon - ir)$ {ϵ = emf, r = internal resistance, V = p.d. required by fan, i = current in each cell, N = the number of cells in each parallel section} [1 mark]

$I = ni$ (I = current required by fan, n = the number of parallel sections) and $Nn = 10$ [1 mark]

e) A cell with a potential of 1.5 V and zero internal resistance is connected to two resistors in parallel, with values $R_1 = 1.0\,\Omega$ and $R_2 = 2.0\,\Omega$, as shown in Fig. 2.2.

(i) Calculate the current through the cell. **[2 marks]**

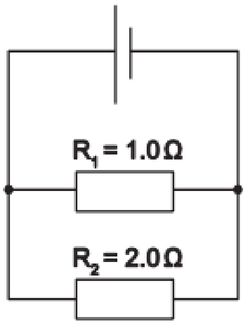


Fig. 2.2

NSAA 2016 Section 2 - Question 2 e (i) - Worked Solution

Reff = 1/(1/1.0 + ½) = 2/3 Ohms
I = V/Reff = 1.5/(2/3) = 2.3A

(ii) If the 1.5 V cell in the circuit shown in Fig. 2.2 is replaced with a 1.5 V cell with an internal resistance $r = 0.10\,\Omega$, how much power is dissipated in R_2? **[2 marks]**

NSAA 2016 Section 2 - Question 2 e (ii) - Worked Solution

Reff’ = 0.1 + 2/3 = 0.76 Ohms
So the new current is V/Reff’ = 1.5/0.76 = 1.96A
Current through R2 is I/3 which can be substituted into the equation for power = (I/3)^2R = 0.85W (R in this equation is the resistance of R2)

(iii) A third resistor $R_3 = 4.0\,\Omega$ is now added in parallel with the first two resistors with the cell from **e(ii)**, as shown in Fig. 2.3. Calculate the current through the cell (which has an internal resistance of $0.10\,\Omega$). **[2 marks]**

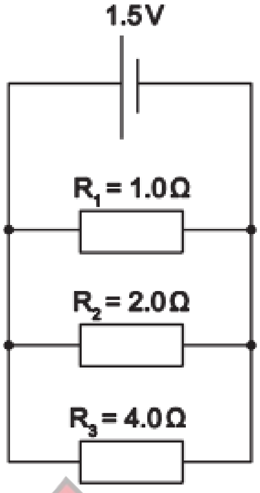


Fig. 2.3

NSAA 2016 Section 2 - Question 2 e (iii) - Worked Solution

Total resistance = 0.1 + 1/(1/1 + ½ + ¼) = 0.67 Ohms
I = V/R = 1.5/0.67 = 2.2A

(iv) More and more resistors are now added, one by one, in parallel with the existing ones, each with double the resistance of the previous one. The final circuit consists of resistors with values of 1 Ω, 2 Ω, 4 Ω, 8 Ω, 16 Ω, 32 Ω, 64 Ω, … connected in parallel with the cell. Calculate the total current through the cell if the number of resistors is infinite.

[3 marks]

NSAA 2016 Section 2 - Question 2 e (iv) - Worked Solution

The reciprocal of the effective resistance of the circuit is an infinite sum of a geometric series:

1/Reff = 1 + ½ + ¼ + … = a/1-r = 1/(1 – ½) = 2

Including the internal resistance as well: R = ½ + 1/10 = 6/10 = 0.6 Ohms

I = V/R = 1.5/0.6 = 2.5A

NSAA Section 2 2016 - Question 3

Question 3

Parts **a)**, **b)** and **c)** can be answered independently of one another.

a) Draw two alternative 'dot and cross' diagrams to describe the bonding in the linear thiocyanate anion SCN^-. In one diagram place the negative charge on the sulfur, and in the other place the negative charge on the nitrogen. **[5 marks]**

NSAA 2016 Section 2 - Question 3 (a) - Worked Solution

Two diagrams to be given here:

Firstly, if the negative charge is on sulphur, there is a single bond (one dot/cross pair) between the carbon and the sulphur and a triple bond (three dot/cross pairs) between carbon and nitrogen. Sulphur has three lone pairs and nitrogen has one.

If the negative charge is on nitrogen, there are double bonds (two dot/cross pairs) between both nitrogen and carbon and sulphur and carbon. There are two lone pairs on nitrogen and two lone pairs on sulphur.

b) Breakfast cereals frequently have elemental iron added to them as a dietary supplement. A method for making a quantitative measurement of the amount of iron is to use the reaction between $Fe^{3+}(aq)$ and thiocyanate, $SCN^{-}(aq)$, which gives the deep red complex $FeSCN^{2+}(aq)$.

$$Fe^{3+}(aq) + SCN^{-}(aq) \longrightarrow FeSCN^{2+}(aq)$$

The depth of the colour can be measured using a *spectrophotometer* which gives a value for the *absorbance* that is proportional to the concentration of the complex:

$$\text{absorbance} = \text{constant} \times [FeSCN^{2+}] \qquad \textbf{Equation 1}$$

The constant can be found by measuring the absorbance of a solution of known concentration.

(i) The absorbance of a solution of the complex with concentration 2.5×10^{-4} mol dm^{-3} was measured to be 1.85; determine the value of the constant in Equation 1. **[2 marks]**

NSAA 2016 Section 2 – Question 3 b (i) - Worked Solution

constant = absorbance / concentration = 1.85/ 2.5x10^-4 = 7400 (no units required but they are mol^-1 dm^3)

100 g of breakfast cereal was mixed with sufficient dilute acid to dissolve all of the iron. The solution was carefully filtered and mixed with sufficient oxidising agent to convert all of the iron to Fe^{3+}. The solution was made up to a total volume of 250 cm^3. 10.0 cm^3 of this solution was mixed with 10.0 cm^3 of a solution of thiocyanate; you may assume that all of the iron is converted to the complex. The absorbance of the resulting solution was measured as 0.519.

(ii) Using the value of the constant found in **(i)**, calculate the concentration of Fe^{3+} in the solution for which the absorbance was measured. **[2 marks]**

NSAA 2016 Section 2 – Question 3 b (ii) - Worked Solution

concentration of Fe^3+ = 0.519/7400 = 7.01 x 10^-5 moldm^-3

(iii) Hence calculate the concentration of Fe^{3+} in the solution prepared from the cereal.

[2 marks]

NSAA 2016 Section 2 – Question 3 b (iii) - Worked Solution

concentration in the 10mL portion of the extract is two times that calculated in part (ii) = 1.403 x 10^-4 moldm^-3 since that had been mixed with 10mL of thiocyanate. This is equal to the concentration of the 250mL sample since it was a sample from there.

(iv) Hence calculate the mass of iron present in the 100 g of breakfast cereal (A_r: Fe = 55.85).

[4 marks]

NSAA 2016 Section 2 – Question 3 b (iv) - Worked Solution

to work out the amount in 100g of the cereal therefore:

moles in 250cm^3 = 1.403 x 10^-4 x (250/1000) = 3.507 x 10^-5

mass of Fe therefore = 3.507 x 10^-5 x 55.85 = 1.96 x 10^-3 g

c) Hydrogen peroxide, H_2O_2, is used as the oxidising agent to convert Fe^{2+} to Fe^{3+} in the assay described in **b)(ii)**.

(i) Determine the oxidation state of oxygen in H_2O_2. **[2 marks]**

NSAA 2016 Section 2 – Question 3 c (i) - Worked Solution

Species is neutral, so assuming oxidation state of hydrogen is +1:

2 x +1 = +2. Therefore total of two oxygens is -2, so each oxygen is -1.

(ii) When H_2O_2 acts as an oxidising agent in acidic solution, what is the oxygen-containing species that is produced and what is the oxidation state of oxygen in this species?

[4 marks]

NSAA 2016 Section 2 – Question 3 c (ii) - Worked Solution

Hydrogen peroxide is reduced to water. The oxidation state of oxygen in water is -2.

(iii) Write a balanced chemical equation describing the oxidation of Fe^{2+}(aq) to Fe^{3+}(aq) by H_2O_2 in acidic solution. **[4 marks]**

NSAA 2016 Section 2 – Question 3 c (iii) - Worked Solution

Write the two half equations first:

$Fe^{2+} = Fe^{3+} + e$

$H_2O_2 + 2H^+ + 2e = 2H_2O$

Multiply Fe equation by 2 to have same number of electrons in both and then combine equations:

$H_2O_2 + 2H^+ + 2e + 2Fe^{2+} = 2H_2O + 2Fe^{3+} + 2e$

Cancel electrons:

$H_2O_2(aq) + 2H^+(aq) + 2Fe^{2+}(aq) = 2H_2O(l) + 2Fe^{3+}(aq)$

NSAA Section 2 2016 - Question 4

Question 4

There are six isomers with the formula C_5H_{10} that are alkenes. The alkenes all have different enthalpies of formation, all of which are negative.

a) Draw the structures of the six alkenes (skeletal or displayed structures are acceptable).

[6 marks]

NSAA 2016 Section 2 – Question 4 (a) - Worked Solution

Six alkenes are:
- 3-methylbut-1-ene
- 2-methylbut-1-ene
- 2-methylbut-2-ene
- Pent-1-ene
- E-pent-2-ene
- Z-pent-2-ene

Samples of the six alkenes, in a random order, are labelled **P**, **Q**, **R**, **S**, **T**, and **U**. You will be able to identify which isomer *some* of these correspond to using the information and data throughout the rest of the question.

Alkenes **P**, **Q**, and **R** react with hydrogen gas and a metal catalyst to give the same alkane **A**; alkenes **S**, **T**, and **U** react under the same conditions to give a different alkane **B**.

Both alkanes **A** and **B** react with chlorine gas under UV light to form chloroalkanes with the formula $C_5H_{11}Cl$. Under such conditions, alkane **A** forms *four* different structural isomers, whereas **B** gives *three*.

b) Draw the structures of alkanes **A** and **B**. Also draw the structures of the four isomers arising from the chlorination of **A**, and the three isomers arising from the chlorination of **B**. **[6 marks]**

NSAA 2016 Section 2 – Question 4 (b) - Worked Solution

There is no reasoning required in the answer to this question, only the isomers.

The two alkane isomers which can be formed are pentane and 2-methylbutane.

The chlorination of pentane gives three isomers: 1-chloropentane, 2-chloropentane and 3-chloropentane.

The chlorination of 2-methylbutane gives four isomers: 1-chloro-2-methylbutane, 2-chloro-2-methylbutane, 1-chloro-3-methylbutane and 3-chloro-2-methylbutane.

This means that with 3 possible isomers from chlorination, alkane B must be pentane and alkane A (with 4 possible isomers from chlorination) must be 2-methylbutane.

The alkenes react with HBr to form bromoalkanes with the formula $C_5H_{11}Br$; the reaction proceeds via a carbocation intermediate. Alkenes **S** and **T** give a mix of *two* structural isomers, whereas alkene **U** gives only one.

c) Give the structure of alkene **U**. **[4 marks]**

NSAA 2016 Section 2 – Question 4 (c) - Worked Solution

S, T and U give alkane B, so must be pent-1-ene, E-pent-2-ene and Z-pent-2-ene. This then requires you to think about the carbocations which would form during the addition reaction; the two pent-2-ene stereoisomers would form 2 different secondary carbocations for the two structural isomers, whereas pent-1-ene would either form a secondary carbocation or a primary one, which won't happen. Therefore, only the isomer which would form from the secondary carbocation would be seen, so the answer is pent-1-ene. (draw out the possible structures in your answer).

A general rule for isomeric alkenes is that the more carbon atoms directly bonded to the double bond (or the lower the number of hydrogen atoms directly bonded), the more negative (that is, the more exothermic) the enthalpy of formation of the alkene.

d) Out of **P**, **Q** and **R**, **R** has the most negative (most exothermic) enthalpy of formation. Give the structure of **R**. **[1 mark]**

NSAA 2016 Section 2 – Question 4 (d) - Worked Solution

R is 2-methylbut-2-ene.

Consider the following thermodynamic data:

	value / kJ mol^{-1}
standard enthalpy change of hydrogenation for alkene **P**	–113
standard enthalpy change of hydrogenation for alkene **Q**	–119
standard enthalpy change of combustion for alkane **A**	–3528
standard enthalpy change of formation of $H_2O(l)$	–286

e) Use the data to deduce the structure of: **(i)** alkene **P**; and **(ii)** alkene **Q**. **[4 marks]**

NSAA 2016 Section 2 – Question 4 (e) - Worked Solution

Hydrogenation of P and Q will both give A. Therefore, enthalpy of formation of P and Q can be compared by comparing their enthalpies of hydrogenation.

P + H2 = A and Q + H2 = A

deltaH (hydrogenation) for these reactions is = deltafH (A) – deltafH (P or Q)

So, deltafH (P or Q) = deltafH (A) – deltaH(hydrogenation)

Since hydrogenation enthalpy is more negative for Q than for P, -deltaH (hydrogenation) is more positive for Q than for P, so deltafH is larger for Q (Q is less negative), so P has the more substituted double bond; P is 2-methylbut-1-ene and Q is 3-methylbut-1-ene.

f) Use the data to calculate the standard enthalpy change of combustion of alkene **P**.

[4 marks]

NSAA 2016 Section 2 – Question 4 (f) - Worked Solution

Write out equations:

Enthalpy of hydrogenation of P = -113:
$C_5H_{10} + H_2 = C_5H_{12}$

Enthalpy of combustion of resulting alkane A = -3528:
$C_5H_{12} + 8O_2 = 5CO_2 + 6H_2O$

Reverse the enthalpy of formation of water = +286:
$H_2O = H_2 + 0.5O_2$

Adding all three together gives:
$C_5H_{10} + 3.5O_2 = 5CO_2 + 5H_2O$

DeltaH for this is -113 – 3528 + 286 = -3355 kJ/mol

NSAA Section 2 2016 - Question 5

Question 5

*Eco*RI is a restriction enzyme that cuts bacterial DNA into pieces at specific sequences.

a) What type of biological molecule is *Eco*RI? **[1 mark]**

NSAA 2016 Section 2 – Question 5 (a) - Worked Solution

Answer: Protein

EcoRI is an enzyme and thus is a protein

b) Name the type of bond between adjacent nucleotides that is cut by *Eco*RI. **[1 mark]**

NSAA 2016 Section 2 – Question 5 (b) - Worked Solution

Answer: Phosphodiester bonds

Nucleotides in a DNA are linked by sugar-phosphate bonds, called phosphodiester bonds.

c) *Eco*RI cuts at specific sites in the DNA, characterised by the sequence GAATTC. Other restriction enzymes cut at specific sequences like GGATCC or AGCT. What characteristic do these sequences have in common and how might this characteristic aid in cutting?

[3 marks]

NSAA 2016 Section 2 – Question 5 (c) - Worked Solution

(1) These sequences are pallindromic.
(2) So reading from the 5' to 3' end of one sequence (ex. GAATTC) would be the same as reading the opposite of the 3' to 5' end of the sequence (i.e. for GAATTC would be CTTAAG).
(3) This allows the restriction enzymes to make cuts on **both** strands of the DNA at the **same** time, leaving 'sticky ends'.

d) *Eco*RI is produced by bacteria. What role might it have in a bacterial cell? **[1 mark]**

NSAA 2016 Section 2 – Question 5 (d) - Worked Solution

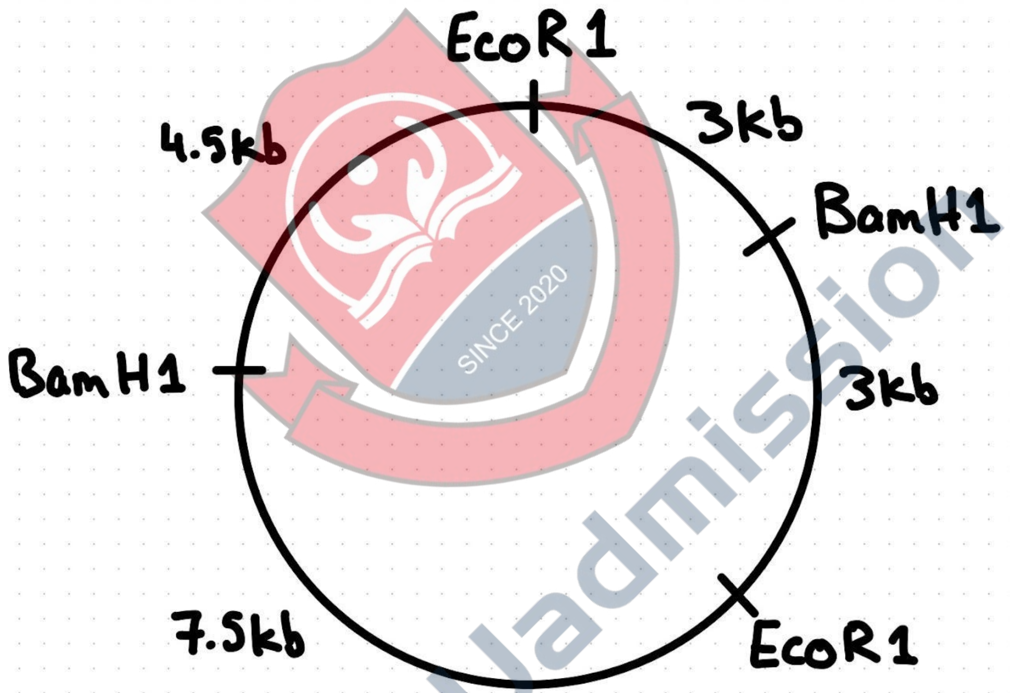
Restriction enzymes in a bacteria help cut up invading viruses for defence.

e) We can use different restriction enzymes to cut DNA at different sites. Another restriction enzyme is *Bam*HI. By studying the fragments produced by different combinations of restriction enzymes we can produce a map of the cutting sites of these enzymes.

Use the data in the table below to produce a map of the cutting sites of restriction enzymes. This map should be drawn onto a circle of bacterial plasmid DNA, the total length of which is 18 kb. Distances between the cut sites should be identified. **[4 marks]**

enzyme used	*fragment sizes produced* / kb
*Eco*RI alone	6, 12
*Bam*HI alone	7.5, 10.5
*Eco*RI and *Bam*HI together	3, 3, 4.5, 7.5

NSAA 2016 Section 2 – Question 5 (e) - Worked Solution



1 mark for drawing a circle with cuts
1 mark for identifying correct number of cuts
1 mark for correct labelling
1 mark for correct diagram

f) Suggest how enzymes like *Eco*RI could be used in genetic engineering. **[3 marks]**

NSAA 2016 Section 2 – Question 5 (f) - Worked Solution

(1) EcoRI is a type of restriction enzyme. These can be used to cut plasmids, allowing us to introduce human genes into the plasmid
(2) The plasmid can then be transferred into a bacterium, and the bacterium grown in a culture The bacteria will then transcribe and translate the human gene introduced, and produce the desired proteins.
(3) An example of this would be producing insulin (for diabetes)

g) *Eco*RI is produced by bacteria that often live harmlessly inside the human body. Explain how temperature and pH might affect the activity of *Eco*RI in bacterial cells, using diagrams if necessary. **[12 marks]**

NSAA 2016 Section 2 – Question 5 (g) - Worked Solution

NB: EcoRI is a restriction enzyme, and thus a protein.

Temperature

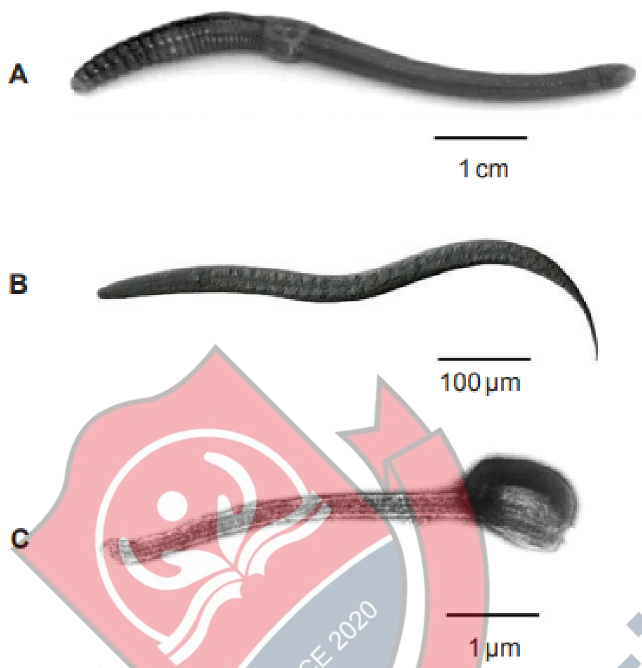
(1) Increasing temperatures initially increase the kinetic energy of the enzyme EcoRI, and increases the frequency of the enzyme-substrate complexes. This results in a higher activity of EcoRI.
(2) Eventually, increasing the temperature beyond a point (ex. above 37 *C in the human body) would denature the enzyme, as the bonds keeping the enzyme in shape would be disrupted. The active site of the EcoRI would no longer be able to bind to the substrate, and fewer enzyme-substrate complexes would form. This would reduce the activity of the EcoRI.
(3) Therefore, a bell curve is observed. The optimum pH would be around 37 *C.

pH
(1) At a low and high pH, the high concentration of H+ and OH- respectively interfere with the bonding within the enzyme. This can impact the secondary and tertiary structure of the enzyme, and thus alter the shape of the active site.
(2) At a neutral pH (around 7), the enzyme will be working at it's fastest (the optimum pH).

NSAA Section 2 2016 - Question 6

Question 6

Below are images of three species of organism, all of which are vermiform (worm-like) in appearance.



a) What is the approximate length of each species in mm? **[3 marks]**

NSAA 2016 Section 2 – Question 6 (a) - Worked Solution

A: 60mm +/-15 mm
B: 0.6 mm +/- 0.15mm
C: 0.005mm +/- 0.0015mm

b) What type of microscope has been used to produce the images of organisms B and C?
[2 marks]

NSAA 2016 Section 2 – Question 6 (b) - Worked Solution

Work out this question using both the size of the organism and how the image appears
B: light microscope
C: Electron microscope (TEM)

c) For organism A, treating it as a tube, estimate the surface area:volume ratio, working in mm. Show your working. **[4 marks]**

NSAA 2016 Section 2 – Question 6 (c) - Worked Solution

Treat as a cylinder

Surface area of a cylinder = 2πrh+2πr^2
Volume of a cylinder = πr^2h

Because the lenght of the worm (h) is much greater than its width (and r), and because we are estimating, we can ignore 2πr^2
S = 2πrh

S/V = 2πrh / πr^2h
= 2/r

You could also estimate the radius of the worm using the reference bar provided to give an answer between 1 mm^-1 and 2mm^1

d) How will the surface area:volume ratio differ between the three organisms? **[2 marks]**

NSAA 2016 Section 2 – Question 6 (d) - Worked Solution

Surface area: volume ratio will decrease as the size of the organism increases

e) Identify four substances that organism A may need to exchange with the external environment.

[2 marks]

NSAA 2016 Section 2 – Question 6 (e) - Worked Solution

Any four of the following:
Oxygen
CO2
Urea
Glucose
Water

f) Discuss how the size of organisms affects their ease of exchange of substances with the external environment. You should highlight at least two adaptations that help overcome the constraints of size. **[12 marks]**

NSAA 2016 Section 2 – Question 6 (f) - Worked Solution

Having a larger surface area: volume allows an organism to exchange substances more easily with its environment.
As the size of an organism increases, the surface area: volume decreases

Many larger organisms have adaptatios to increase the exchange surface areas to allow more effecient exchange
An example of this are the gills of a fish, which are used to extract oxygen from the water
They are adapted to do this effectively by:
Being highly folded, giving a larger surface area. The gill filaments have gill lamellae to further increase surface area
using a counter-current exchange system, where the blood of the fish and water are flowing in opposite directions. This maximises the amount of oxygen that is able to diffuse into the blood by maintaining the concentration gradient for passive diffusion.

Conversely, a large SA:volume may cause issues, e.g. dehydration
For example, cacti have spines instead of leaves to reduce the SA: voluime to reduce water loss