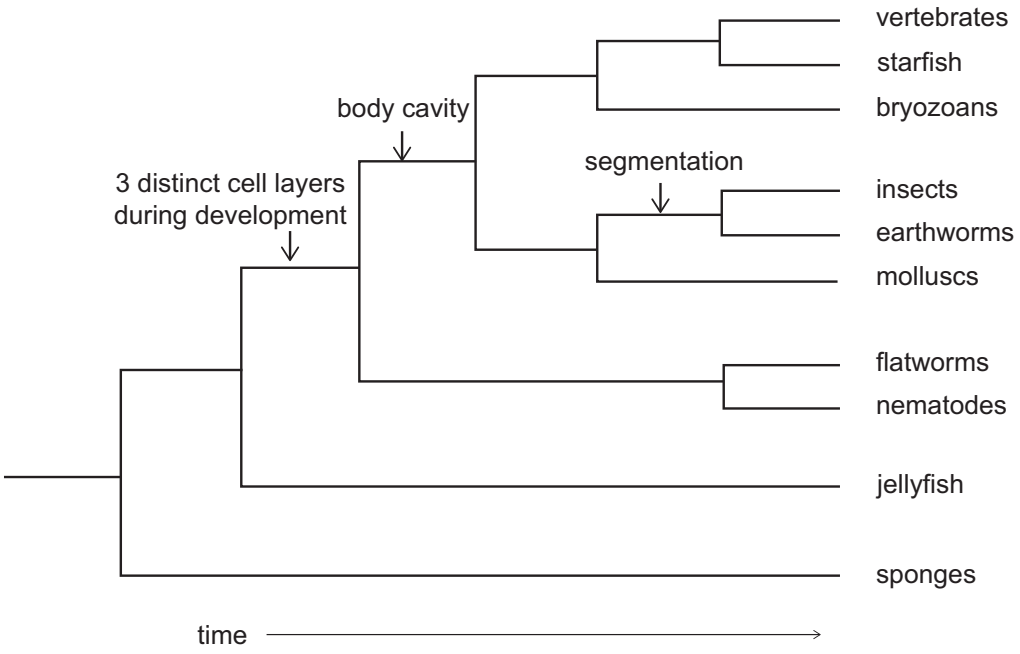
Biology

Question B1

The diagram shows an evolutionary tree for a kingdom of organisms. This tree was constructed over 20 years ago using shared observable features to group these organisms into smaller groups. The time at which three of these shared features first appeared is shown on the evolutionary tree. Each branching point in the tree indicates the time at which groups of organisms diverged from a common ancestor.



a) Identify the kingdom represented in this evolutionary tree.

[1 mark]

Answer: ANIMALIA.....

……

……

b) Recently, molecular evidence has changed our understanding of these relationships. Based upon each of the three findings below, what conclusions about evolution can you draw?

(i) Insects and earthworms are not closely related to each other.

[1 mark]

Answer: ……

Segmentation is not a good indicator of relatedness/ it must have evolved independently (or ancestrally)

(ii) Nematodes and insects, both of which undergo moulting, are very closely related.

[2 marks]

Answer: ……

Moulting arose in their common ancestor and is a good indicator of relatedness (1 Mark).

The above tree is incorrect (1 mark).

(iii) Flatworms, which all lack a true body cavity, are not actually a single group. Some diverged at the base of the tree, some are related to the molluscs, and some are related to starfish and vertebrates.

[2 marks]

Answer: ……

Absence of body cavity is not a good indicator of relatedness (1 mark).

It must have been lost independently, or the body cavity arose on many separate occasions (1 mark).

c) Briefly describe two benefits of using molecular evidence to construct trees, rather than visible characteristics.

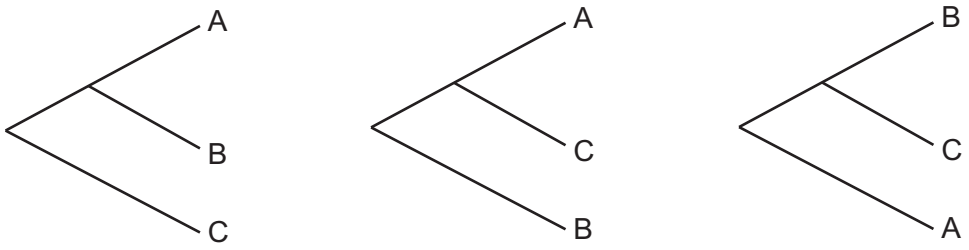
[2 marks]

Answer: .....

Genetics provides a huge amount of data that can be used to construct trees (1 mark).

There is less convergence at the molecular level (1 mark)

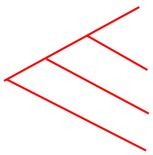
d) The following three tree diagrams show **all** of the possible relationships between 3 different organisms.



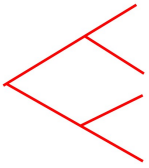
How many possible tree diagrams are there with 4 organisms? **[2 marks]**

Answer:

There are 15 trees, 12 with branching patterns of:



….and a further 3 with a different branching pattern:.



1 Mark should be awarded for an answer of 12, and 2 Marks for an answer of 15.

e) Using examples, discuss the different ways by which we can measure biodiversity.

[10 marks]

Answer: .....

There are basic points that should be made, but beyond this additional marks may be accrued for further insights

Basic points:

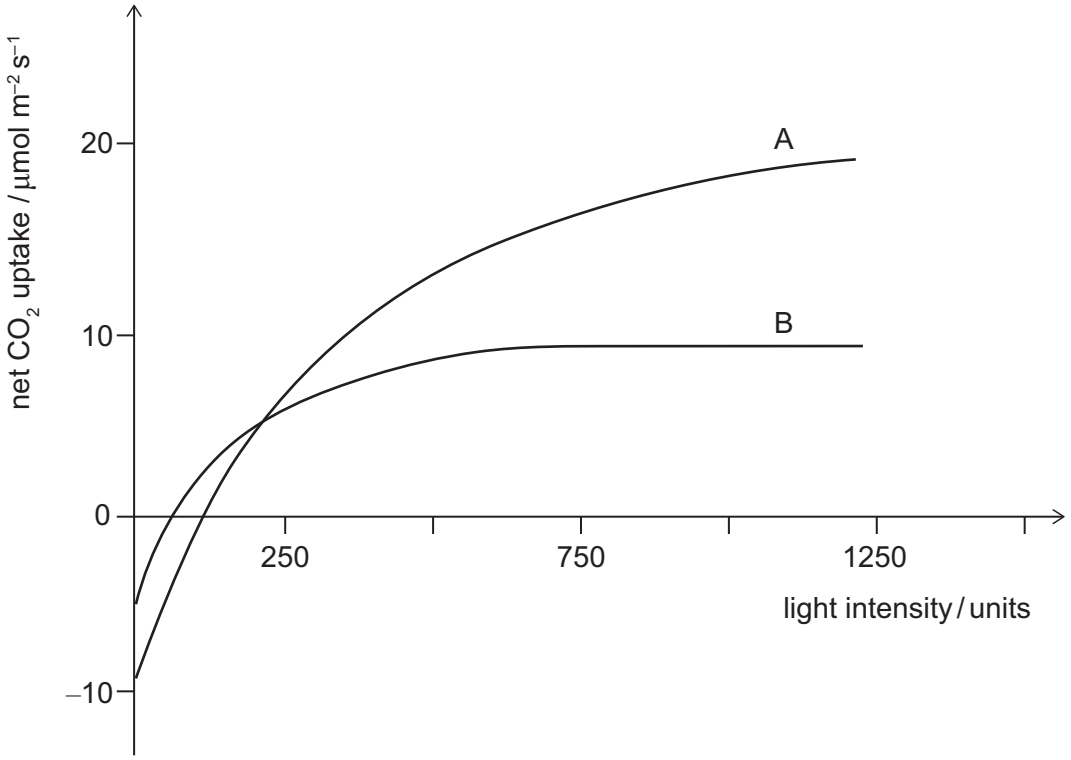
1. **Definition: the variety and complexity of life**
2. **Can be measured at a Genetic level**
3. **Can be measured at a Population level**
4. **Can be measured at a Habitat level (i.e. no species)**

Advanced points:

1. **Description of genetic variation**
2. **Mention of the importance of mutation in causing genetic differences**
3. **Discussion of the quantification of genetic differences (within + between species)**
4. **Discussion of classificatory systems**
5. **Discussion of the concept of a species**
6. **Mention that new new classificatory systems move beyond observable features**
7. **Mention of the role of Natural selection in causing diversity**
8. **Discussion of behavioural, physiological and anatomical adaptations**
9. **Mention of how quadrats and belt transects are used to investigate the distribution and abundance of organisms in a habitat.**
10. **Explanation of how to determine the number of organisms in a given area.**
11. **2 bonus points may be added for particularly in-depth descriptions of advanced conserations**

Question B2

The graph shows net CO_2 uptake of two different plants, A and B, when exposed to increasing light levels.



a) Name two physiological processes that affect the net CO_2 uptake in plants.

[1 mark]

Answer: Photosynthesis + respiration

b) State what can be concluded when the net CO_2 uptake in each plant is zero.

[1 mark]

Answer: The rate of photosynthesis is equal to the rate of respiration

c) For plant B, estimate the value at which increasing light intensity no longer affects CO_2 uptake.

[1 mark]

Answer: **650-700** (some 1/2 marks were given if the student was close)

d) Estimate the number of micromoles of CO_2 that would be taken up by a 50 cm^2 leaf of plant B in one minute at light intensity of 750 units.

[2 marks]

Answer: **9 x 0.005m^2 x 60 =2.7µmol (2.4 -2.9 accepted)**

(1 mark lost for each unit not adjusted)

e) Propose two explanations for the existence of a plateau in the curve for plant B.

[2 marks]

Answer:

Factors other than incident light limit photosynthesis (1 mark).

These may include temperature, CO_2 levels, or enzymatic activity of the enzymes involved in the process (1 mark each, including if 1st mark not awarded).

f) Describe the differences in the curves for plants A and B and suggest why these differences might occur.

[3 marks]

Answer:

Plant B has a higher CO2 uptake in low light intensities (1 mark)

Plant B reaches a lower plateau (light saturation point) (1 mark)

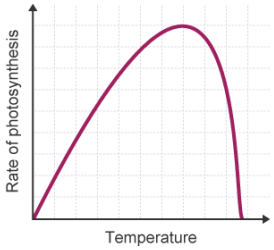
It would be found in plants that are adapted to living in low light conditions (1 mark)

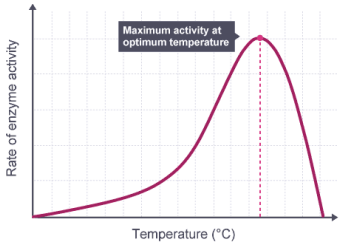
g) Discuss how temperature might affect net CO_2 uptake in plants, with reference to the effects of temperature on enzymatic activity. Use graphs to illustrate your answer.

[10 marks]

Answer:

Students should discuss both photosynthesis and respiration, using reaction curves. There are basic points that should be made, but beyond this additional marks may be accrued for further insights





Basic points (1 mark each):

1. **Depends upon relative rates of photosynthesis and respiration**
2. **Balance largely mediated through relative effects on enzyme activity**
3. **At low temperatures, rates are limited by molecular collisions between enzymes and substrates**
4. **A high temperatures, effects caused by denaturation of enzymes**
5. **Reaction curve for photosynthesis**
6. **Reaction curve for respiration (this may be generic)**

Advanced points (1 mark each):

1. **Mention of range of temperatures at which photosynthesis functions (0-50 degrees C) (or generic respiration)**
2. **Mention of optimum temperatures for photosynthesis (15-40 degrees C) (or generic respiration)**
3. **Comparisons of different types of plant**
4. **Mention of interactions with other limiting factors**
5. **Mention of anaerobic/aerobic effects**
6. **Mention of specific molecules involved in photosynthetic and respiratory reactions.**
7. **Attempt to super-impose and compare curves**
8. **Mention of temperature effects on diffusion of gases**
9. **Specific details on denaturation processes in enzyme**
10. **Anything else that is relevent.**
11. **2 bonus points may be added for particularly in-depth descriptions of advanced conserations**

Question 1

Data: Assume that the molar gas volume = 24.0 dm^3 mol^{-1} at room temperature and pressure (rtp).

This question concerns the chemistry of tellurium, an element in Group 16 of the periodic table.

a) What do you expect will be the maximum and minimum oxidation states of tellurium? Briefly explain your answer. [3 marks]

b) How do you expect the electronegativity of the elements to vary on descending Group 16? [1 mark]

c) Which of the hydrides H_2O and H_2Te do you expect will have the higher boiling point? Briefly explain your answer. [2 marks]

Tellurium reacts directly with fluorine gas to form a dense gas, **A**, in which each molecule contains a single tellurium atom bonded to several fluorine atoms. In an experiment, 50 cm^3 of gas **A** is formed from 150 cm^3 of fluorine and a certain mass of tellurium, all measurements made at room temperature and pressure.

d) Calculate the formula of the gas **A**. [2 marks]

e) Predict the value(s) of the F—Te—F bond angles in **A**. [1 mark]

f) Calculate the minimum mass of tellurium needed to produce 50 cm^3 of **A**. [2 marks]

g) Calculate the density of gas **A** in g cm^{-3} at room temperature and pressure. [2 marks]

h) Calculate how many times denser gas **A** is than oxygen gas. [1 mark]

In another experiment, 5.0 g of tellurium is oxidised and dissolved in water to form 9.0 g of an acid with general formula H_mTeO_n. On neutralisation with aqueous KOH, 18 g of a salt is formed with general formula K_mTeO_n.

i) Give an expression, in terms of m and n, for the oxidation state of the tellurium in the acid H_mTeO_n. [1 mark]

j) Calculate the relative molecular mass of the acid H_mTeO_n. [1 mark]

k) Calculate the values of m and n and hence the formulae of the acid H_mTeO_n and the salt formed on neutralisation. [2 marks]

l) Calculate the volume of a 2.0 mol dm^{-3} aqueous solution of KOH that would be needed to neutralise the 9.0 g of acid formed from 5.0 g of tellurium. [2 marks]

Answers for Question 1

a) Minimum oxidation state = -2 (Te needs 2 electrons for noble gas configuration) Maximum oxidation state = +6 (all six of its valence electrons being used in bond formation). **[3]**

b) Electronegativity decreases on moving down a group. **[1]**

c) (Generally boiling points for analogous hydrides in a group would increase with the mass of the molecule), but due to hydrogen bonding. H_2O would have the higher boiling point. **[2]**

d) Since only one Te atom present molecule, 3 moles of F2 form 1 mol of gas A. So 1 mol of A must containt 6 mols of F, i.e. A is TeF_6. **[2]**

e) Octahedral stucture, so F—Te—F must be 90°. **[1]**

f) Moles of A = 50/24000. Mass of Te = 127.6 x 50/24000 = 0.266 g **[2]**

g) Density = [127.6+(6x19)]/24000 = 0.01007 g cm^{-3}. **[2]**

h) Ratio of densities = ratio of molar masses = [(6x19)+127.6]/32 = 7.55 **[1]**

i) 2n – m **[1]**

j) 9.0 g of acid contains 5.0 g of Te. So one mole of Te (127.6 g) would be in 127.6 x 9.0 / 5.0 = 230 g. **[1]**

k) RMM of salt = 127.6 x 18 / 5.0 = 459.

459 – 230 = 39m – m
so m = 6.0
n = [230 -127.6 – 6]/16 = 6
Formulae are H_6TeO_6 and K_6TeO_6. **[2]**

l) moles of acid = 5 / 127.6
moles of KOH needed = 6 x 5 / 127.6
volume needed = 6 x 5 x 1000 / (127.6 x 2) = 117 cm^3. **[2]**

Question 2

Trifluoroethanoic acid, TFEA, is a carboxylic acid often used in organic chemistry and has the formula CF_3COOH. The density of TFEA is 1.489 g cm^{-3}.

a) Draw the structure for trifluoroethanoic acid (TFEA). Indicate on your structure the approximate bond angles around each carbon. [2 marks]

An aqueous solution of TFEA is made up by mixing 0.0700 mol of the pure acid with water and making the solution up to 100.0 cm^3.

b) Calculate the volume of pure TFEA needed to make the solution. [3 marks]

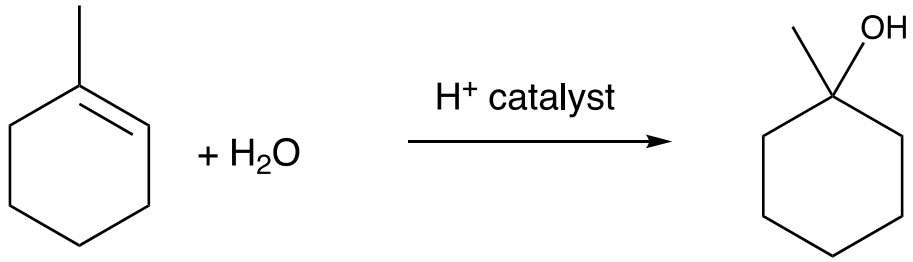
c) Give an equation for the ionization of the TFEA in water. [1 mark]

d) Give an expression for the equilibrium constant for the ionization of TFEA in water. [2 marks]

e) Given that the measured concentration of H^+ ions is 0.4119 mol dm^{-3}, calculate the value of the equilibrium constant. You may ignore the self-dissociation of water. [3 marks]

A mixture of TFEA and trifluoroethanoic anhydride, $CF_3COOCOCF_3$, was used as the solvent system in a series of experiments to determine the standard enthalpy changes of hydration of various alkenes.

1-methylcyclohexene, **A**, may be hydrated in an acid-catalysed reaction as shown below:



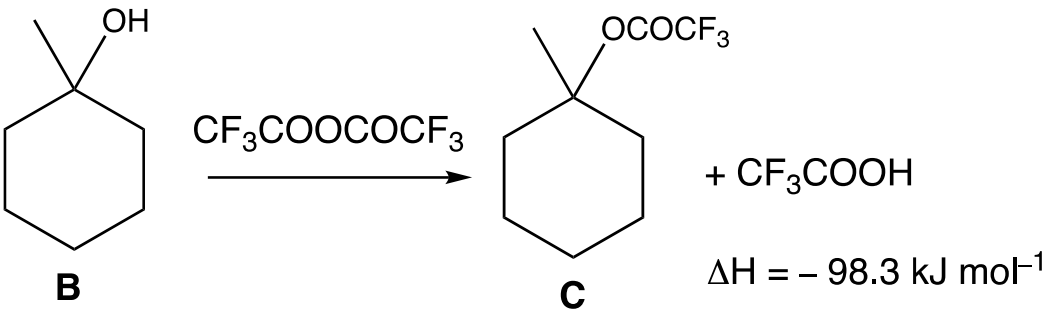
A **B**

f) How may this reaction be classified? Choose from addition, elimination, substitution, oxidation, addition polymerisation. [1 mark]

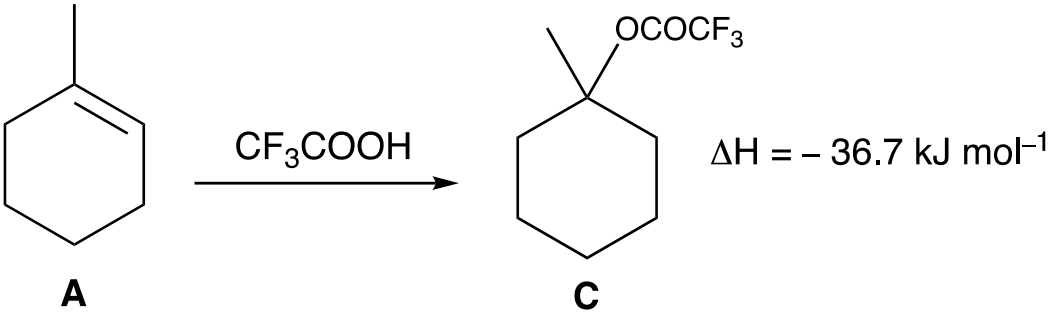
g) Draw the structure of the species initially formed when the H^+ catalyst reacts with alkene **A**. [1 mark]

h) The same product **B** is formed when an alkene isomer of **A** is treated under identical conditions. Suggest a structure for this isomer. [1 mark]

In a mixture of TFEA and trifluoroethanoic anhydride, **B** reacts with the trifluoroethanoic anhydride to form **C** and TFEA as shown below. The standard enthalpy change for this reaction is –98.3 kJ mol^{-1}.



Compound **C** may also be formed in the same mixture of TFEA and trifluoroethanoic anhydride from the reaction between 1-methylcyclohexene and trifluoroethanoic acid. The standard enthalpy change for this reaction is –36.7 kJ mol^{-1}.



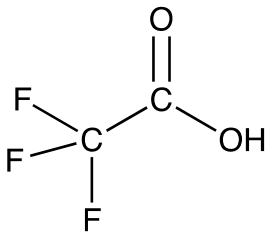
The standard enthalpy change for the reaction between one mole of water and one mole of trifluoroethanoic anhydride is –75.6 kJ mol^{-1}.

i) Give the structure of trifluoroethanoic anhydride. [1 mark]

j) Give the equation for the reaction between one mole of water and one mole of trifluoroethanoic anhydride. [1 mark]

k) By constructing an appropriate energy cycle, calculate the standard enthalpy changes for the hydration of alkene **A**. [4 marks]

Answers for Question 2



a) Angles round CF3 carbon approximately 109.5°.
Angles round carbonyl carbon approximately 120°. **[2]**

b) RMM of TFEA = 114. Mass of TFEA needed = 0.0700 x 114 = 7.98 g
1.489 g has a volume of 1 cm3. So 7.98 g has a volume of 7.98/1.489 = 5.36 cm^3. **[3]**

c) $CF_3COOH(aq) \rightleftharpoons CF_3COO^-(aq) + H^+(aq)$ **[1]**

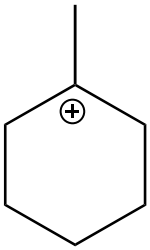
d) $K_{eq} = [CF_3COO^-][H^+] / [CF_3COOH]$ **[2]**

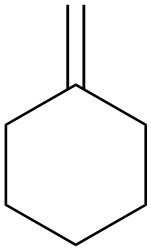
e) $[CF_3COO^-] = [H^+] = 0.4119$ mol dm^{-3}.

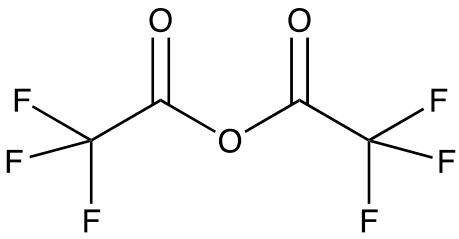
$[CF_3COOH] = 0.700 – 0.4119 = 0.2881$ mol dm^{-3}.

K_{eq} = 0.4119^2 / 0.2881 = 0.589 **[3]**

f) addition **[1]**

g)  **[1]**

h)  **[1]**

i) 

[1]

j) $CF_3COOCOCF_3 + H_2O \longrightarrow 2\ CF_3COOH$ **[1]**

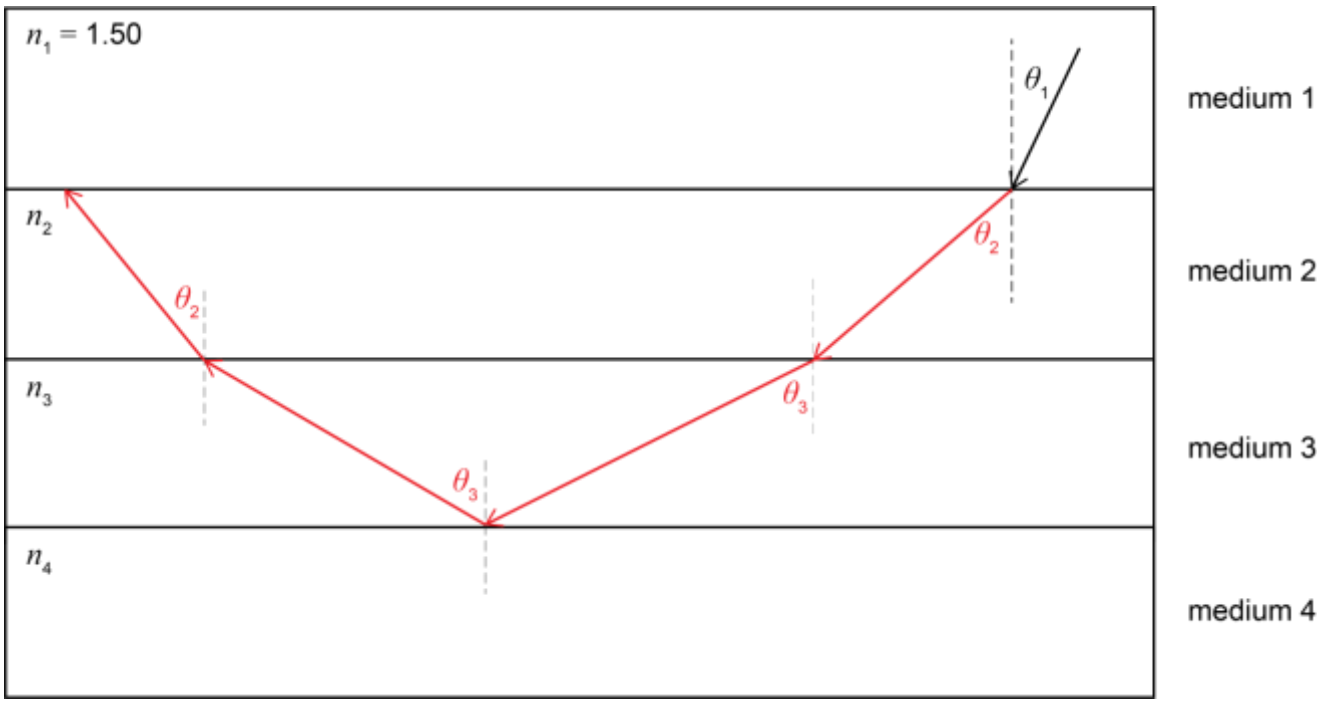
k) $\Delta H = –36.7 – 75.6 + 98.3 = –14.0$ kJ mol^{-1}. **[4]**

NSAA S2 2019 Mark scheme

Answers for Question P1

a) [TOTAL = 7 marks]

i)



[1 mark] for correctly showing each ray bending away from the normal.
[1 mark] for showing reflection or critical condition at n_3, n_4 boundary.

ii) **[1 mark]** Snell's Law $n_1 \sin\theta_1 = n_2 \sin\theta_2$
$n_2 \sin\theta_2 = n_3 \sin\theta_3$
$n_3 \sin\theta_3 = n_4 \sin 90$

[1 mark] Realising that $\theta_4 = 90^\circ$ (or in form $\sin C = \frac{1}{n}$)
[1 mark] answer,

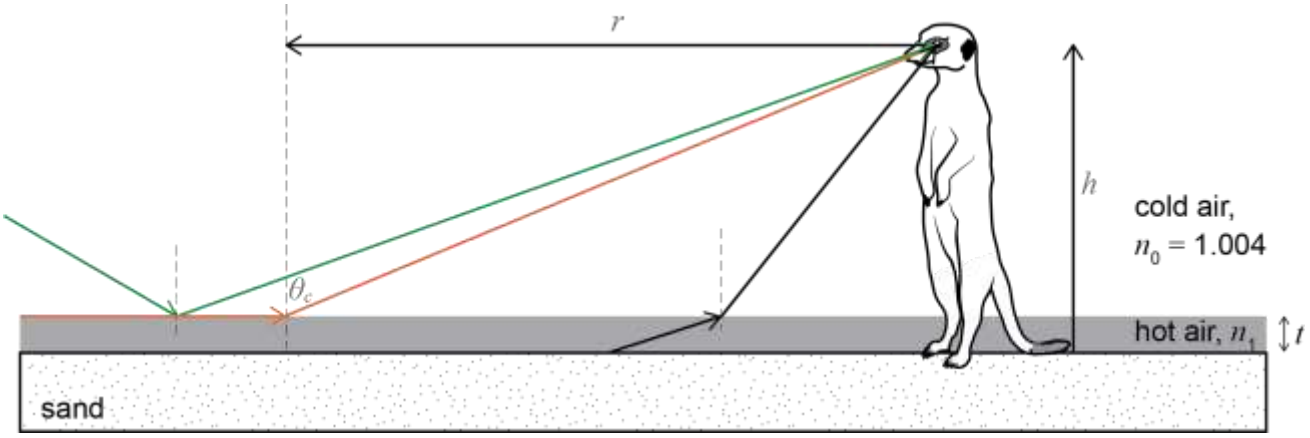
$$\sin\theta_1 = \frac{n_4}{n_1}$$

$$\theta_1 = \arcsin\frac{n_4}{n_1}$$

iii) **[1 mark]** $n_4 = 1.50 \times 0.99^3 \approx 1.46$ (1.4554),
[1 mark] $\theta_1 = \arcsin(0.99^3) \approx 76^\circ$ ($76.001^\circ = 1.326$ rad),

b) [TOTAL = 8 marks]

i)



Green ray. [**1 mark**]
Black ray. [**1 mark**]

ii) Orange ray [**1 mark**]

$n_1 \sin 90 = n_0 \sin\theta_c$ **[1 mark]**
$\sin\theta_c = n_1 / n_0$ [**1 mark**]

iii) $\frac{r}{\sqrt{(r^2+h^2)}} = \frac{R}{\sqrt{(R^2+H^2)}}$ (from Snell's Law and sine of the angle)

Equally $\tan\theta_c$ has to be the same for both animals therefore

$\frac{R}{r} = \frac{H}{h}$ [**1 mark**] **Note:** 0.5 mark for $\frac{R}{r} = \frac{H-t}{h-t}$ as $t \ll h \ll H$ has not been considered

iv) $n = n_c \sin\theta_c$ [**1 mark**]

$n = \frac{n_c\, r}{\sqrt{h^2+r^2}}$ [**1 mark**] this mark is for correctly expressing $\sin\theta_c$ in terms of r and h

$r^2(n_c^2 - n^2) = h^2 n^2$

$r = \frac{hn}{\sqrt{n_c^2 - n^2}}$ therefore a=1, b=1, k= -1 [**1 mark in total for the 3 coefficients any coefficient wrong = 0**]

v) as the hot air gets hotter n decreases therefore the denominator gets bigger and the numerator gets smaller so r must get smaller (h and n are constant). Need numerator and denominator [**1 mark**]

r gets smaller [**1 mark**]

note: that although the question says "using the expression" we would also give **1 mark** for the explanation that if the hot air cooled to the temperature of the cold air you would "see" no water therefore if the air got hotter the island must shrink and r get smaller.

note: students will give the incorrect answer gets "bigger" if they have not taken the critical angle from the normal but to the horizontal by mistake

c) A = refraction [**1 mark**]
B = total internal reflection [**1 mark**]

Answers for Question P2

a) $E_p = \frac{1}{2}kx^2$ **[1 mark,** if students went on to write something that was incorrect then **1/2]**

b) $E_k = \frac{1}{2}mv^2$ **[1 mark,** if students went on to write something that was incorrect then **1/2]**

c) $\frac{\mathrm{d}E_p}{\mathrm{d}t} = kxv$ **[1 mark if clearly shown that** $\frac{\mathrm{d}E_p}{\mathrm{d}x} = kx$ **and that** $\frac{\mathrm{d}x}{\mathrm{d}t} = v$**]**

$\frac{\mathrm{d}E_k}{\mathrm{d}t} = \frac{\mathrm{d}E_k}{\mathrm{d}v}\frac{\mathrm{d}v}{\mathrm{d}t}$ **[1 mark for correct chain rule]**

$\frac{\mathrm{d}E_k}{\mathrm{d}t} = mva$ **[1 mark]**

d) **The total energy of the system must remain constant** therefore the rate of change of the total energy = 0; (note: stating energy is conserved is sufficient for the mark) **[1 mark]**

e) $\frac{dE_T}{dt} = kxv + mva = 0$ **[1 mark]**

$kx = -ma$

$a = -\frac{k}{m}x$ **[1 mark]**

$\therefore f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ **[1 mark]**

note: the question explicitly asks students to show all of their working so if they just write down the answer they only achieve 1 mark. It also asks that they use part c) and d). If they use forces rather than parts c) & d) only 1 mark given.

note: if students gave a physical incorrect answer (i.e. $f = \frac{-1}{2\pi}\sqrt{\frac{k}{m}}$ or $f = \frac{1}{2\pi}\sqrt{-\frac{k}{m}}$ then the mark was not given. Benefit was given if students wrote $f = \pm\frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

f) $k_{\text{eff}} = 2k + \frac{k}{2} = \frac{5k}{2}$ **[1 mark, each spring ½ mark – if the student indicated the incorrect result for series or parallel then 0 mark** (e.g. parallel = $\frac{k}{2}$) **]**

$\therefore f_{\text{new}} = \frac{1}{2\pi}\sqrt{\frac{5k}{2m}}$ **[1 mark]**

g) $E_p = \frac{1}{2}k(x + X)^2$ **[1 mark]**

$E_p = \frac{1}{2}k(x - X)^2$ gets 0 marks as the spring is extended by $(x + X)$ (if students indicated vectors the negative permitted)

h) $E_k = \frac{1}{2}(mu^2 + Mv^2)$ **[1 mark]**

i) Ideal answer is to state that the momenta of each particle must be equal and opposite for the centre of mass to remain stationary, therefore $mu = Mv$ and integrating gives $mx = MX$. **[1 mark]**

Note: COM stationary is stated in the questions but benefit [1 mark] was given for stating this as the reason as long as students did not them go on to give further incorrect discussion. Students often referred to moments for the reason $mx = MX$ [0 mark]. If the answer was ambiguous or imprecise then 0 mark was given. Conservation of momentum without further information = 0, Newton's third law without detail of relevance = 0). In summary, the examiners gave the mark for an explanation **in words** that was precise and demonstrated a thorough understanding of the system.

$a_M = \frac{ma_m}{M}$ **[1 mark]** can be positive or negative.

Note: Credit was given for $a_M = \frac{xa_m}{x}$, although xa_M is not a useful physical quantity, as long as the reasoning for the expression was correct and clear.

j) $E_T = \frac{1}{2}kx^2\left(1+\frac{m}{M}\right)^2 + \frac{1}{2}\left(mu^2 + \frac{Mm^2}{M^2}u^2\right)$ **[1 mark]** this mark is for correctly substituting for X and v in terms of x and u. This may be done at this stage by the student or after the next step – the mark should be given irrespective of when the substitution happens.

$\frac{dE_T}{dt} = kxu\left(1+\frac{m}{M}\right)^2 + mua_m + \frac{m^2}{M}ua_m = 0$ **[1 mark]**

Note: if students solve this question by analogy then **[1 mark]** for the correct coefficient of kxu and **[1 mark]** for the correct coefficient of mua.

$kxu\left(1+\frac{m}{M}\right)^2 + mua_m\left(1+\frac{m}{M}\right) = 0$

$\frac{k}{m}x\left(1+\frac{m}{M}\right) + a_m = 0$

$a_m = -k\left(\frac{1}{m}+\frac{1}{M}\right)x$

$\therefore f = \frac{1}{2\pi}\sqrt{k\left(\frac{1}{m}+\frac{1}{M}\right)}$ or $\frac{1}{2\pi}\sqrt{k\left(\frac{M+m}{mM}\right)}$ **[1 mark]**

k) $f = 6.65\times10^{13}$ Hz **[1 mark,** if previous frequency expression wrong but numbers applied correctly 1 ecf given**]**

$\lambda = \frac{3\times10^8}{6.65\times10^{13}} = 4.5(1)\,\mu\text{m} \approx 4500\,\text{nm}$ therefore **Infra-red** **[1 mark]**

Note: Students were given the mark for just stating (knowing) infra-red.