Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2016

Marking Scheme

Physics and Chemistry

Higher Level

Note to teachers and students on the use of published marking schemes

Marking schemes published by the State Examinations Commission are not intended to be standalone documents. They are an essential resource for examiners who receive training in the correct interpretation and application of the scheme. This training involves, among other things, marking samples of student work and discussing the marks awarded, so as to clarify the correct application of the scheme. The work of examiners is subsequently monitored by Advising Examiners to ensure consistent and accurate application of the marking scheme. This process is overseen by the Chief Examiner, usually assisted by a Chief Advising Examiner. The Chief Examiner is the final authority regarding whether or not the marking scheme has been correctly applied to any piece of candidate work.

Marking schemes are working documents. While a draft marking scheme is prepared in advance of the examination, the scheme is not finalised until examiners have applied it to candidates' work and the feedback from all examiners has been collated and considered in light of the full range of responses of candidates, the overall level of difficulty of the examination and the need to maintain consistency in standards from year to year. This published document contains the finalised scheme, as it was applied to all candidates' work.

In the case of marking schemes that include model solutions or answers, it should be noted that these are not intended to be exhaustive. Variations and alternatives may also be acceptable. Examiners must consider all answers on their merits, and will have consulted with their Advising Examiners when in doubt.

Future Marking Schemes

Assumptions about future marking schemes on the basis of past schemes should be avoided. While the underlying assessment principles remain the same, the details of the marking of a particular type of question may change in the context of the contribution of that question to the overall examination in a given year. The Chief Examiner in any given year has the responsibility to determine how best to ensure the fair and accurate assessment of candidates' work and to ensure consistency in the standard of the assessment from year to year. Accordingly, aspects of the structure, detail and application of the marking scheme for a particular examination are subject to change from one year to the next without notice.

General Guidelines

In considering this marking scheme the following points should be noted.

1. In many instances only key words are given, words that must appear in the correct context in the candidate's answer in order to merit the assigned marks.

2. Marks shown in brackets represent marks awarded for partial answers as indicated in the scheme.

3. Words, expressions or statements separated by a solidus, /, are alternatives which are equally acceptable.

4. Answers that are separated by a double solidus, //, are answers which are mutually exclusive. A partial answer from one side of the // may not be taken in conjunction with a partial answer from the other side.

5. The descriptions, methods and definitions in the scheme are **not** exhaustive and alternative valid answers are acceptable. Marks for a description may be obtained from a relevant diagram, depending on the context.

6. Where indicated, one mark is deducted for incorrect / no units.

7. Each time an arithmetical slip occurs in a calculation, one mark is deducted.

8. Cancellation may apply when a candidate gives a list of correct and incorrect answers.

9. The context and the manner in which the question is asked and the number of marks assigned to the answer in the examination paper determines the detail required in any question. Therefore, in any instance, it may vary from year to year.

10. Bonus marks at the rate of 10% of the marks obtained will be given to a candidate who answers entirely through Irish and who obtains less than 75% of the total marks. In calculating the bonus to be applied decimals are always rounded down, not up e.g., 4.5 becomes 4; 4.9 becomes 4, etc. The bonus table given on the next page applies to candidates who answer entirely through Irish and who obtained more than 75% of the total marks.

Coimisiún na Scrúduithe Stáit

400@10%

Marcanna Breise as ucht freagairt trí Ghaeilge

Léiríonn an tábla thíos an méid marcanna breise ba chóir a bhronnadh ar iarrthóirí a ghnóthaíonn níos mó ná 75% d'iomlán na marcanna.

N.B. Ba chóir marcanna de réir an ghnáthráta a bhronnadh ar iarrthóirí nach ngnóthaíonn níos mó ná 75% d'iomlán na marcanna don scrúdú. Ba chóir freisin an marc bónais sin **a shlánú síos**.

Tábla 400 @ 10%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 400 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 300 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
301 - 303	29
304 - 306	28
307 - 310	27
311 - 313	26
314 - 316	25
317 - 320	24
321 - 323	23
324 - 326	22
327 - 330	21
331 - 333	20
334 - 336	19
337 - 340	18
341 - 343	17
344 - 346	16
347 - 350	15

Bunmharc	Marc Bónais
351 - 353	14
354 - 356	13
357 - 360	12
361 - 363	11
364 - 366	10
367 - 370	9
371 - 373	8
374 - 376	7
377 - 380	6
381 - 383	5
384 - 386	4
387 - 390	3
391 - 393	2
394 - 396	1
397 - 400	0

Question 1
Any eleven parts **11×6**

(*a*) Distinguish between speed and velocity. **2×3**
speed is a scalar / speed is distance travelled per second / speed = distance ÷ time / speed is rate of change of distance …3
velocity is a vector / velocity is distance per second in a given direction /
velocity = distance ÷ time in a given direction / velocity is rate of change of displacement …3

(*b*) State the property of a body of mass *m* moving with velocity *v* defined by (*i*) *mv*, (*ii*) ½*mv*^{2}. **2×3**
(*i*) momentum …3
(*ii*) kinetic energy …3
[allow 1 for energy in (*ii*)]

(*c*) Mass A moving at 20 m s^{-1} collided with a stationary 3 kg mass B. After the collision both objects moved together with a velocity of 8 m s^{-1}. What was the mass of A? **2×3**
$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ / $m(20) + 3(0) = (m + 3)8$ / $m(20) + 3(0) = m(8) + 3(8)$ …3
($m(20) = m(8) + 24 \Rightarrow 12m = 24 \Rightarrow m =$) 2 (kg) ...3

(*d*) Define the unit of energy, ie. the joule. **2×3**
the work done when a force of 1 newton …3
moves its point of application 1 m in the direction of the force ...3
[Allow 5 marks for 1 J = 1 N m.]
[‘in the direction of the force omitted’ (–1)]

(*e*) A pin is placed 15 cm from a concave mirror of focal length 10 cm. How far from the mirror is the image formed? **2×3**
$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ / $\frac{1}{10} = \frac{1}{15} + \frac{1}{v} \Rightarrow \frac{1}{v} = \frac{1}{30}$ …3
($v =$) 30 (cm) …3

(*f*) Select from the list that follows the type of electromagnetic radiation that has (*i*) the longest wavelength, (*ii*) photons of the greatest energy.

gamma rays **microwaves** **ultraviolet rays** **x-rays**

2×3
(*i*) microwaves …3
(*ii*) gamma rays …3

(*g*) Name a phenomenon of light that be explained *only* in terms of its wave nature. **6**
diffraction, interference, polarisation, etc …6

(*h*) What thermometric property is used in
(*i*) a liquid in glass thermometer,
(*ii*) a constant-volume gas thermometer? **4, 2**
(*i*) height / volume / length //
(*ii*) pressure
first correct...4, second correct …2

(*i*) What are the two fixed points (reference temperatures) on the Kelvin scale of temperature? **4, 2**

0 K / absolute zero / –273.15 °C //
273.16 K / triple point of water / 0.01 °C
first correct...4, second correct …2

(*j*) State Coulomb's Law of force between electric charges <u>2×3</u>
the force between two point charges is directly proportional to the product of their charges ...3
and inversely proportional to the square of the distance between them ...3

or

$F = k\frac{Q_1Q_2}{d^2}$ / $F \propto \frac{Q_1Q_2}{d^2}$ ...3
explain all the terms ...3
[product omitted ...(−1)] [sum instead of product...(−3)] [square omitted…(−3)]

(*k*) Calculate the effective capacitance of the arrangement of capacitors shown in Figure 1. <u>2×3</u>
1 + 1 = 2 (μF) ...3
($\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$ / $\frac{1}{C} = \frac{1}{4} + \frac{1}{2} \Rightarrow \frac{1}{C} = \frac{3}{4} = 0.75 \Rightarrow C =$) 1.333 or $\frac{4}{3}$ μF ...3
[failure to invert …(−1)]
[Allow 6 (μF) …3]

(*l*) Fleming's left hand rule for the force on a current-carrying conductor in a magnetic field is shown in Figure 2. If the forefinger indicates the direction of the magnetic field, what quantity is represented by arrow (*i*) X, (*ii*) Y? <u>2×3</u>
(*i*) force / movement …3
(*ii*) current …3
[reversed…3]

(*m*) Explain why the core of a transformer, like that shown in Figure 3, conserves energy
(*i*) when it is made of *soft* iron,
(*ii*) when it is laminated. <u>2×3</u>
(*i*) easier to magnetize and demagnetize the core / eliminates hysteresis losses …3
(*ii*) reduces eddy currents …3
[allow (3) for 'to reduce heat loss' but once only]

(*n*) When projected from the same starting point, at the same velocity, into the same magnetic field, an alpha-particle and a beta-particle are both deflected onto circular paths. State two ways their deflections differ. <u>2×3</u>
deflection is greater for beta particles / beta has bigger radius (of deflection) …3
deflection is in the opposite direction …3

(*o*) The mass loss in a nuclear reaction is 1.6×10^{-29} kg. How much energy is released in the reaction? <u>4, 2</u>
$E = mc^2$ …4
$E = 1.6 \times 10^{-29} \times (3 \times 10^8)^2 = 1.44 \times 10^{-12}$ (J) ...2

Question 2

(*a*) Define

(*i*) mass, <u>**4**</u>

(*i*) amount of matter in an object / measure of resistance to movement / measure of inertia …4

(*ii*) weight. <u>**4**</u>

(*ii*) force of gravity on an object / mass × acceleration due to gravity …4

Classify each of these quantities as a vector or as a scalar. <u>**2, 2**</u>

mass is a scalar …2

weight is a vector …2

(*b*) A student in Ireland carried out experiments to measure *g* the acceleration due to gravity at the surface of the Earth.

(*i*) Draw a labelled diagram of a suitable apparatus. <u>**3×3**</u>

string, bob // ball, trapdoor // any free falling object, e.g. a weighted card …3

point of suspension, split cork // electromagnet / timer // light gate(s) …3

labels …3

(*ii*) What two sets of measurements should have been taken by the student using this apparatus? <u>**4, 2**</u>

length of the pendulum, l //distance from electromagnet to trapdoor, s or l or d // distance between light gates, s or l or d

time for (one) oscillation, T // time for fall, t // t_1 and t_2 (and hence final velocity, v)
[allow mark for l, s or d if drawn or shown on diagram]

first correct...4, second correct …2

Using the data obtained, the student drew a suitable straight line graph through the origin.

(*iii*) Sketch this graph labelling the axes correctly. <u>**2×3**</u>

square of periodic time or T^2 // T // length of free fall / s or l or d // final velocity squared / v^2 …3

length of string // $\sqrt{l}$ // s or l or l // time for fall squared / t^2 // distance fallen from rest / s or l or d …3

[unlabelled axes with straight line through origin ….1]

(*iv*) Describe how *g* was calculated using the graph. <u>**2×3**</u>

$T = 2\pi\sqrt{\frac{l}{g}}$ / $T^2 = 4\pi^2\frac{l}{g}$ // $s = ½ gt^2$ // $v^2 = 2gs$ // find slope m …3

$g = \frac{4\pi^2}{m}$ / $\sqrt{g} = \frac{2\pi}{m}$ // $g = 2 \times m$ // $g = ½ \times m$ …3

[allow $g = 4\pi^2 m$ / $\sqrt{g} = 2\pi m$ // $g = 2 \times 1/m$ // $g = \frac{1}{2} \times \frac{1}{m}$ if consistent with graph in (*iii*)]

(*v*) A student in Kenya also measured *g*. See Figure 4. Note that the radius of Earth at any point on the Equator is greater than its radius at Ireland.

Explain how you would expect the average value for *g* measured in Kenya to differ from than that measured in Ireland. <u>**2×3**</u>

(g) smaller (in Kenya) …3

force of gravity is smaller at equator / g related to distance from object to centre of earth …3

(*c*) Figure 5, not drawn to scale, shows a car at point *P* travelling horizontally at 5 m s^{-1}. At *P* it accelerates at 2.5 m s^{-2} for 8 s and reaches a velocity *v* at *Q* and then continues at this constant velocity for 20 s. The car is brought to rest at *R* by uniform braking over a further 30 s.

(*i*) Calculate the velocity *v* of the car after the first 8 s. **2×4**

$v = u + at$ / $v = 5 + 2.5(8)$ …4

(v =) 25 m s^{-1} …4

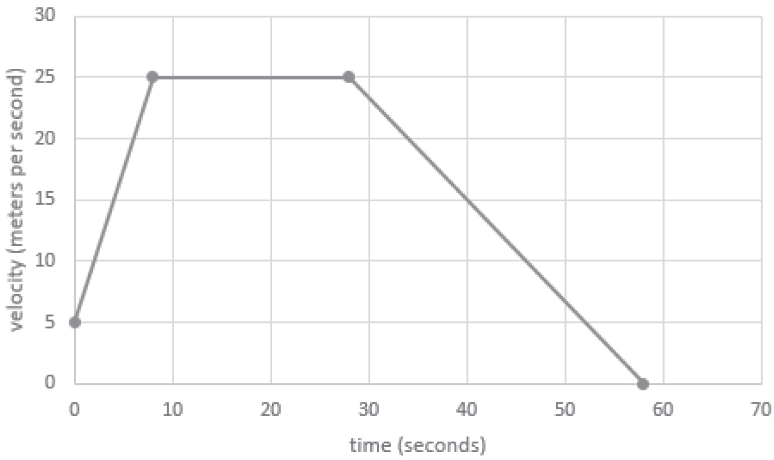
[no unit or incorrect unit (–1)]

(*ii*) Draw, on graph paper, a velocity-time graph to represent the motion of the car from *P* to *R*. **3×3**

axes labelled correctly and scaled correctly …3

acceleration phase correct …3

constant velocity or deceleration phase correct ...3



(*iii*) Find the distance travelled by the car at constant velocity. **2×2**

$s = vt$ / distance = velocity × time …2

25 × 20 = 500 m …2

[no unit or incorrect unit (–1)]

Question 3

(*a*) State *Snell's law* of refraction <u>2×3</u>

sine of the angle of incidence // sin *i* // ratio of sine of the angle of incidence to the sine of the angle of refraction // $\frac{\sin i}{\sin r}$ …3

is proportional to the sine of the angle of refraction // $\propto$ sin *r* // is a constant or equal to the refractive index or *n* or *μ* // is a constant or equal to the refractive index or *n* or *μ* …3

(*b*) Define

(*i*) refractive index, <u>2×3</u>

(*i*) $\frac{\sin i}{\sin r}$ // $\frac{c_1}{c_2}$ // $\frac{1}{\sin c}$ // $\frac{\text{RD}}{\text{AD}}$ …3

explain *i* and *r* // explain c_1 and c_2 // explain *C* // explain RD = real depth and AD is apparent depth …3

(*ii*) critical angle. <u>2×3</u>

(*ii*) the angle of incidence in the more dense medium …3

when the angle of refraction is 90° …3

[in the more dense medium omitted …(–1)]

(*c*) Using a block of glass, a beam of white light and a protractor, a student obtained data to verify Snell's law. The graph shown in Figure 6 was obtained using the angles of incidence *i* measured in air and the corresponding angles of refraction *r*.

(*i*) Explain how the graph verifies Snell's law. <u>2×3</u>

straight line …3

through the origin …3

(*ii*) Use the graph to find the refractive index of this glass. <u>2×3</u>

$\frac{y_2-y_1}{x_2-x_1} = \frac{0.9}{0.5}$ (= slope of graph / refractive index) …3

(*n* or *μ*) = 1.8 …3

(*iii*) Find the angle of refraction corresponding to an angle of incidence (in air) of 35º. <u>3×3</u>

$\frac{\sin 35}{\sin r} = 1.8$ // sin35 = 0.57 …3

$\sin r = \frac{\sin 35}{1.8} \Rightarrow \sin r = 0.3187$ // from graph corresponding sin*r* = 0.32 …3

$\sin^{-1}0.32 = 18.6°$ …3

(*iv*) Calculate the critical angle for this glass. <u>3×3</u>

$\frac{1}{\sin c} = 1.8$ …3

$\sin c = \frac{1}{1.8} \Rightarrow \sin c = 0.5556$ …3

$\sin^{-1}0.5556 = 33.75°$ …3

(*v*) Name the phenomenon that occurs when a ray of light strikes the glass/air boundary at an angle of incidence of 40°. <u>3</u>

total internal reflection …3

(*d*) An astronomical telescope in *normal adjustment* has two convex lenses, A and B, arranged as in Figure 7. Lens A has a focal length of 180 cm. The distance between the centres of A and B is 195 cm.

(*i*) Name lenses A and B. **<u>2×3</u>**
A = objective lens …3
B = eyepiece lens …3

(*ii*) How far from lens A is the first image formed? **<u>3</u>**
180 cm ...3
[no unit or incorrect unit (–1)]

(*iii*) When the telescope is in normal adjustment, where is the final image formed? **<u>3</u>**
at infinity ...3

(*iv*) Why is it an advantage to have the telescope in normal adjustment? **<u>3</u>**
prevents eye strain / relaxed eye …3

Question 4

(*a*) Consider a fixed mass of gas at constant temperature.
Name and state the law (A) governing the changes in the pressure of this gas as its volume changes. **3×3**

Boyle's Law …3
the volume of a (fixed mass of) gas at constant temperature / the pressure of a (fixed mass of) gas at constant temperature ...3
varies inversely with its pressure / varies inversely with its volume ...3

Copy Figure 8 in your answerbook and label the axes so that it represents a graph verifying law A. **2×3**

pressure // volume …3
1/volume //1/pressure …3
[units not required on axes]

(*b*) Consider a fixed mass of gas at constant pressure.
Name and state the law (B) governing the changes that take place in its volume as the gas is heated. **3×3**

Charles' Law …3
the volume of a (fixed mass of) gas at constant pressure ...3
varies directly with its absolute temperature ...3

Make another copy of Figure 8 in your answerbook and label the axes so that it now represents a graph verifying law B. **2×3**
volume …3
temperature in kelvin …3
[no units or incorrect unit on temperature axis ...(–1)]

(*c*) Distinguish between a real gas and the ideal gas. **5, 1**
the ideal gas obeys the gas laws or Boyle's Law or the assumptions of the kinetic theory ...5
at all temperatures and pressures / under all conditions (of temperature and pressure) ...1

or

a real gas does not obey the gas laws or Boyle's Law or the assumptions of the kinetic theory ...5
except at high temperatures and low pressures ...1

State two assumptions of the kinetic theory that hold true for the ideal gas but not for a real gas. **4, 2**
no attractive or repulsive forces between the particles of the gas / collisions are elastic /
diameters of the particles are negligible compared to the distances between them
first correct ...4, second correct …2

Under what condition of pressure does a real gas most resemble the ideal gas? **3**
low (pressure) ...3

(*d*) Airplane tyres must perform through a broader temperature range and withstand different types of stresses compared to the tyres on road vehicles, e.g. the sudden increase in pressure on landing, as in Figure 9. For safety reasons airplane tyres are often filled with nitrogen gas instead of air.

(*i*) Calculate the number of moles of nitrogen gas occupying a volume of 0.380 m^3 at a pressure of 1.60 × 10^6 Pa inside an airplane tyre on the ground where the temperature is 295 K. <u>**5, 2×3**</u>

$PV = nRT$ …5

$1.6 \times 10^6 \times 0.38 = n \times 8.31 \times 295$ …3

$n = 248.016 = 248$ (moles) …3

(*ii*) Calculate the pressure inside this tyre at high altitude where the temperature of the gas in the tyre has decreased by 40 °C and the volume occupied has decreased to 0.350 m^3. <u>**2×3**</u>

$PV = nRT \quad \Rightarrow P \times 0.35 = 248 \times 8.31 \times 255$ / $\dfrac{P_1 \times V_1}{T_1} = \dfrac{P_2 \times V_2}{T_2}$ / $(\Rightarrow) \dfrac{1.6 \times 10^6 \times 0.38}{295} = \dfrac{P_2 \times 0.35}{255}$ …3

$P = 1.5 \times 10^6$ Pa or N m^{-2} / $P_2 = 1.5 \times 10^6$ Pa or N m^{-2} …3

[no unit or incorrect unit (–1)]

(*iii*) How does the velocity of the molecules within the airplane tyre change as a result of the change in conditions from (*i*) to (*ii*) above? Explain. <u>**2×2**</u>

slower …2

temperature proportional to kinetic energy / kinetic energy decreases as temperature decreases / kinetic energy increases as temperature increases …2

Question 5

(*a*) Define electrical potential difference (*V*) between two points. **2×3**

the work done (against the electric field) ...3

in moving unit charge or a charge of one coulomb from one point to the other ...3

or

$$V = \frac{W}{q}$$ …3

V, W, q explained …3

What is the SI unit of potential difference? **3**

volt / V ...3

(*b*) In an experiment the potential difference *V* across a 0.5 m length of nichrome wire of uniform diameter, kept at constant temperature, was measured for different values of current *I* flowing in the wire. The following data was obtained.

I **(A)**	**0.5**	**1.0**	**2.0**	**2.5**	**3.0**	**3.5**	**4.5**
V **(units)**	**0.71**	**1.43**	**2.86**	**3.57**	**4.29**	**5.01**	**6.43**

(*i*) Draw a labelled diagram of a suitable electric circuit to obtain these measurements. **3×3**

voltmeter across or in parallel with wire or resistor …3

ammeter or milliameter or galvanometer in series with wire or resistor …3

method to vary voltage in circuit or use of different power sources …3

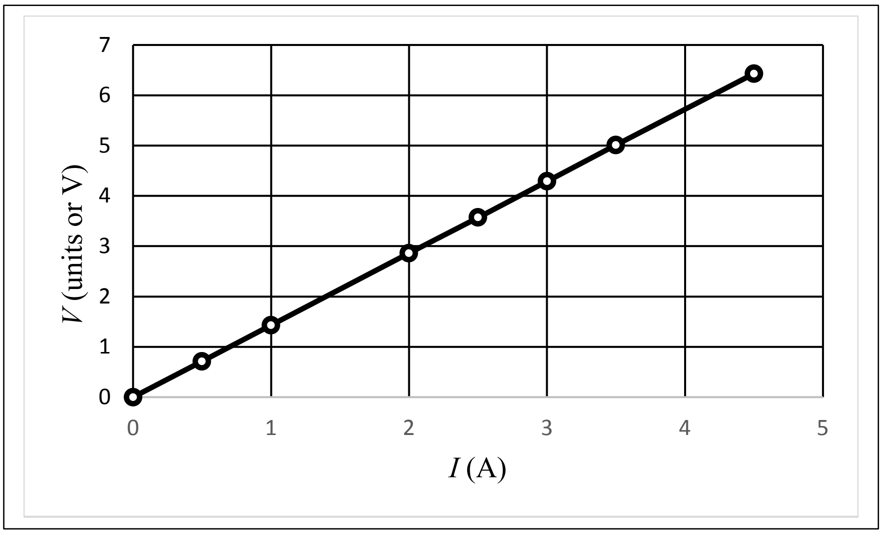
(*ii*) Plot a graph of potential difference *V* (*y*-axis) against current *I*. **4×3**

axes labelled correctly with quantity or unit ...3

axes scaled correctly ...3

points plotted correctly ...3

straight line through the origin ...3



(*iii*) State and name the law verified by your graph. **3×3**

potential difference or voltage across a resistor is proportional to …3

current flowing provided temperature is constant …3

Ohm’s law …3

(*iv*) Use your graph to find the potential difference that allows a current of 1.8 A to flow. **6**
2.55 – 2.6 (V or units) …6
[incorrect reading of graph (–1)]

(*v*) Find the slope *m* of your graph. **2×3**
$\frac{y_2 - y_1}{x_2 - x_1} = \frac{5.72}{4.0}$ …3
(m =) 1.43 …3

What property of the wire is given by *m*? **3**
resistance …3

(*vi*) How would you expect the value of *m* change if a 1.0 m length of the same nichrome wire was used instead of the 0.5 m? **3**
m is doubled / m gets bigger ...3

Justify your answer. **3**
resistance increases as the length of the conductor increase the resistance increases / resistance proportional to length / $R = \frac{\rho l}{A}$ / $R \propto l$ ...3

Explain why high voltage is used to transmit electricity over long distances. **6**
keep current low / reduce heat loss (due to resistance) …6
[Allow reduce costs, more economic, etc ….3]

Question 6
Answer any two parts.

Question 6(*a*)
Define
(*i*) potential energy **3**
energy due to position or condition / mgh …3
[omit to explain m, g, h (–1)]

(*ii*) work. **3**
product of force and displacement or (straight line) distance / done when a force moves a body / done when a force moves its point of application / $(W) = F \times s$ …3
[omit to explain F, s (–1)]

High-diving made its debut at the World Aquatic Championships in Barcelona in 2013. Men dive from a 27 m high platform and women from a 20 m platform, as shown in Figure 10.
Calculate
(*iii*) the change in potential energy of a diver of mass 65 kg from the instant he stepped off the 27 m high platform until he entered the water, having dropped straight down, **2×3**
$(E_p =)\ mgh =$ …3
$65 \times 9.8 \times 27 = 17199$ J …3
[no unit or incorrect unit (–1)]

(*iv*) the vertical velocity of the diver just before he entered the water, **3×3**
$(E_p = E_k =)\ 17199\text{ J} = \frac{1}{2} mv^2$ / $v^2 = u^2 + 2as$ …3
$\frac{2\times17199}{65} = v^2$ / $v^2 = 2 \times 9.8 \times 27$ …3
$v = \sqrt{529.2} = 23\text{ m s}^{-1}$ …3

(*v*) the time taken to fall 27 m. **2×3**
$v = u + at$ / $23 = 0 + 9.8\,t$ / $s = ut + \frac{1}{2}at^2$ / $27 = \frac{1}{2}(9.8)t^2$ …3
$(t =)\ 2.35$ s …3
[no unit or incorrect unit (–1)]

Does the mass of the diver affect his final velocity before entering the water? Explain. **2×3**
no effect …3
all objects accelerate under gravity at same rate (whatever their mass) …3

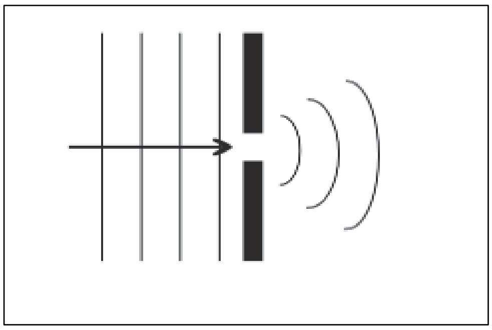
Question 6(*b*)

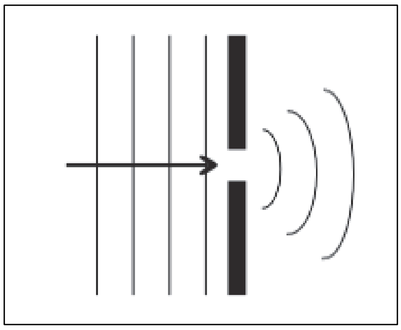
What phenomenon is defined as *the spreading out of waves into the geometrical shadow of an obstacle*? 3

diffraction ...3

Figure 11 represents waves A and B approaching gaps of equal width.

Copy and complete the diagram in your answerbook to show the waves having passed through the gaps. 3×3





diffraction (spreading into geometrical shadow) shown …2×3

more diffraction with shorter wavelength for same gap …3

Monochromatic light fell on a pair of Young's slits 0.02 mm apart and produced an interference pattern on a screen. The second bright fringe made an angle of 3.7° with the normal.

Calculate

(*i*) the wavelength of the light, 3×3

$n\lambda = d\sin\theta$ …3

$2 \times \lambda = 0.02 \times 10^{-3} \times \sin 3.7$ …3

[$\lambda = 6.45 \times 10^{-7}$ m or 645 nm …3

[no unit or incorrect unit (–1)]

[negative answer ⇒ radians used instead of degrees; (–1) and apply consequential marking]

[$\lambda = 5.81 \times 10^{-7}$ m or 581 nm consistent with use of gradians instead of degrees; (–1) and apply consequential marking]

(*ii*) the frequency of the light, 2×3

$c = f\lambda$ / $3 \times 10^{8} = f\,6.45 \times 10^{-7}$ …3

$f = 4.65 \times 10^{14}$ Hz …3

[no unit or incorrect unit (–1)]

(*iii*) the energy of a photon of light of this frequency. 2×3

$E = hf$ ...3

$E = 6.6260693\times10^{-34} \times 4.65\times10^{14} = 3.08 \times 10^{-19}$ J …3

[no unit or incorrect unit (–1)]

Question 6(*c*)

State three effects of an electric current. **3×3**

heating …3

magnetic …3

chemical …3

Which of these effects

(*i*) is used to define the unit of current, i.e. the ampere, **3**

magnetic ...3

(*ii*) causes a filament bulb to produce incandescent light? **3**

heating ...3

A 100 W filament bulb can be replaced by a 25 W CFL (compact fluorescent lamp), like that shown in Figure 12, without any reduction in the brightness of the light emitted.
Assuming a 230 V mains supply, calculate the current flowing through

(*i*) a 100 W filament bulb, **2×3**

$P = VI$ / $100 = 230I$ …3

(I =) 0.435 A …3

[no unit or incorrect unit (–1)]

(*ii*) a 25 W CFL. **3**

($P = VI$ / $25 = 230I \Rightarrow I$ =) 0.109 A / 0.435 ÷ 4 = 0.109 A …3

[no unit or incorrect unit (–1)]

Calculate the cost saving in a week when a 100 W bulb in use for 5 hours a day is replaced by a 25 W bulb. Take the cost of a unit of electricity (1 kW h) as 20 cent. **6**

(75 ÷ 1000) × 5 × 20 × 7 = 52.5 = 53 cent or €0.53 6

[Allow no rounding of cost and rounding of cost up or down to nearest cent]

[Attempt involving conversion of W to kW …3]

[fail to subtract …(–1)]

Suggest a benefit to the environment of switching to CFLs. **3**

saves electricity / cuts down on the use of fossil fuels / reduces CO_2 emissions / less acid rain / reduces SO_2 emissions ...3

Question 6(*d*)

(*i*) Define the half-life of a radioisotope. **2×3**

the time taken for …3

half a sample (of a radioactive substance) to decay / activity (of a sample) to be reduced by half ...3

The table below shows the mass of sample of sodium–24 at 10 hour intervals over a 70 hours period.

time (hours)	0	10	20	30	40	50	60	70
mass (mg)	400	260	160	100	65	40	25	13

(*ii*) Draw a graph to represent this data. **4×3**

axes labelled correctly with quantity or unit ...3

axes correctly scaled ...3

points correctly plotted ...3

curve drawn ...3

(*iii*) Use the graph to determine the half-life of sodium–24. **6**

15 hours ...6

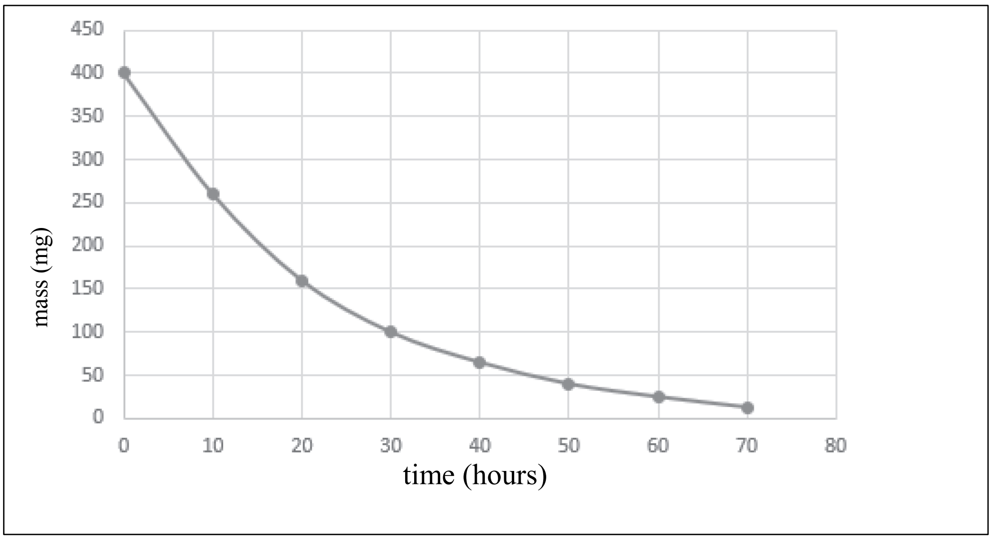
(*iv*) Write an equation to represent the beta-decay of a sodium–24 nucleus. **6**

$^{24}_{11}Na \rightarrow\ ^{24}_{12}Mg\ +\ ^{0}_{-1}e$ ...6

[one product correct ...3]

(*v*) Because of its short half-life, sodium–24 is sometimes injected into patients as a tracer to help diagnose circulatory dysfunction. State one precaution that should be observed by the medical personnel administering the injection to minimize their own exposure to radiation. **3**

wear dosimeter / monitor exposure / wear lead apron / don't handle with fingers, etc ...3



Question 7
Any eleven parts **<u>11×6</u>**

(*a*) How many (*i*) electrons (*ii*) protons, are there in the Al^{3+} ion? **<u>2×3</u>**
(*i*) 10 electrons …3
(*ii*) 13 protons …3

(*b*) Define relative atomic mass. **<u>4, 2</u>**
average mass of an atom of an element taking isotope abundances into account / weighted average mass of isotopes //
compared to 1/12th carbon-12
[average omitted (–1)][1/12th omitted (–1)][taking isotope abundances into account omitted (–1)]
first part correct...4, second part correct …2

(*c*) The 2010 Nobel Prize in Physics was awarded for pioneering work on graphene, a form of the element carbon shown in Figure 13.
Name two other physical forms of the element carbon. **<u>2×3</u>**
diamond / graphite / soot / lampblack / buckministerfullerene / (carbon) nanotubes
any two …2×3

(*d*) The relationship $E_1 – E_2 = hf$ applies when a sodium street light glows.
What do the terms E_1 and f, represent? **<u>2×3</u>**
E_1: energy (of excited state or ground state) / energy of outer shell or inner shell / an energy level …3
f: frequency (of yellow light) emitted …3

(*e*) What is the maximum number of electrons that can be accommodated in
(*i*) a *p* orbital,
(*ii*) a *d* subshell? **<u>2×3</u>**
(*i*) 2 …3
(*ii*) 10 …3

(*f*) Select two molecular crystals from the following list of solids.
gold dry ice sodium chloride iodine **<u>4, 2</u>**
dry ice //
iodine
first correct...4, second correct …2

(*g*) Taking the valency of gallium (Ga) as three, write the formula for the simplest compound formed from (*i*) gallium and nitrogen, (*ii*) gallium and oxygen. **<u>4, 2</u>**
(*i*) GaN //
(*ii*) Ga_2O_3
first correct...4, second correct …2

(*h*) Write a balanced equation for the reaction that occurs when a small piece sodium is dropped into water as shown in Figure 14. **<u>6 or 2×3</u>**
$Na + H_2O \rightarrow NaOH + \frac{1}{2}H_2$ / $2Na + 2H_2O \rightarrow 2NaOH + H_2$ …6

or

formulae correct …3
balancing …3
[allow 3 marks for one correct product if no other marks awarded]

(*i*) **Why does a H_2O molecule have a dipole moment but a BeF_2 molecule does not?** <u>**2×3**</u>

in water the centre of positive charge does not coincide with the centre of negative charge / in water individual dipole moments along bonds don't cancel …3

in BeF_2 the centre of positive charge coincides with the centre of negative charge / in BeF_2 individual dipole moments along bonds cancel …3

[Reference to 'symmetry' **un**acceptable unless in sufficient detail; 'charges cancel' is **not** acceptable.]

(*j*) **Define *heat of combustion.*** <u>**2×3**</u>

heat change when the one moles of a substance / heat evolved when one mole of a substance ...3

is burned completely / is burned in excess oxygen ...3

(*k*) **Under what circumstances can sodium chloride conduct electricity?** <u>**4, 2**</u>

molten //

dissolved (in water) / in (aqueous) solution

[when ions are free to move…3 marks]

first correct ...4, second correct …2

(*l*) **Calculate the percentage by mass of oxygen in cubic zirconia (ZrO_2) used to make the dental implants shown in Figure 15.** [O = 16; Zr = 91] <u>**2×3**</u>

(M_r of ZrO_2) = 123 ...3

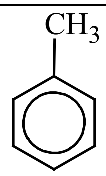
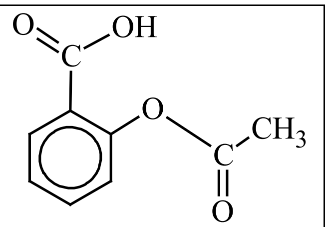
$(\frac{32}{123} \times 100) = 26.(016)\%$ ...3

(*m*) **Identify the reagent required and the necessary condition for the conversion of CH_4 to CH_3Cl.** <u>**2×3**</u>

chlorine / Cl_2 …3

ultraviolet (light) / uv (light) / sunlight ...3

(*n*) **The molecular formula for methylbenzene, shown on the left in Figure 16, is C_7H_8.**
What is the molecular formula for aspirin shown on the right? <u>**6**</u>

	
methylbenzene = $\mathbf{C_7H_8}$	aspirin = ?

$C_9H_8O_4$
…6

[Any two elements correctly counted allow…3]

(*o*) **Name a reagent used to distinguish an aldehyde from a ketone.** <u>**6**</u>

Fehling's or Benedict's (solutions) / ammoniacal silver nitrate or Tollens' (reagent) ...6

[Allow (dilute) acidified MnO_4^- or (dilute) acidified permanganate or (dilute) acidified dichromate or Brady's reagent or phenylhydrazine]

Question 8

(*a*) Define (*i*) atomic number, <u>**3**</u>

number of protons (in nucleus of an atom) …3

(*ii*) the first ionisation energy of an element. <u>**3×3**</u>

the minimum energy required to remove the electron ...3

most loosely bound …3

from one mole of neutral gaseous atoms ...3

[one mole omitted …(–1)] [minimum omitted…(–1)]

(*b*) Plot a graph of first ionisation energy *versus* atomic number, for the elements with atomic numbers 3 to 12 inclusive, using the values on page 80 of the *Formulae and Tables* booklet. <u>**6, 3×3**</u>

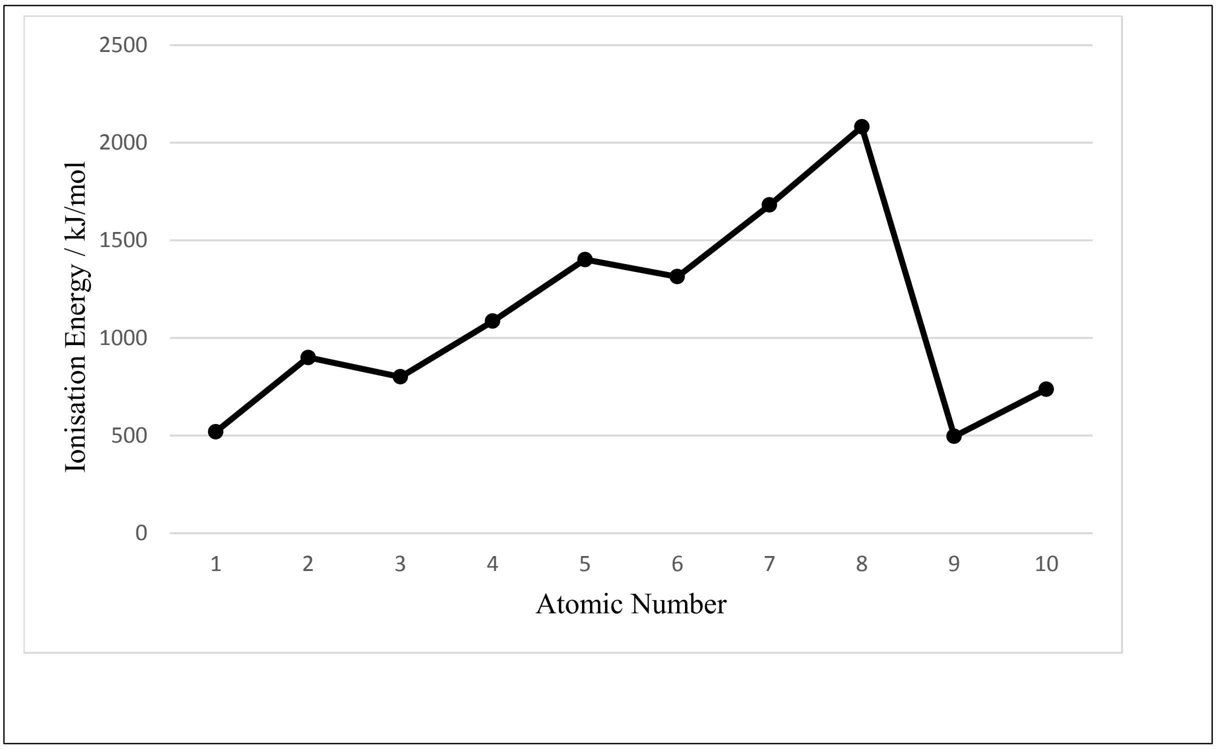
both axes labelled (ionisation energy or unit and atomic number or element name or symbol) …6

7 points plotted correctly …3

last three points plotted correctly …3

points joined …3

[graph paper not used …(–3)]



(*i*) Referring to your graph, explain the general increase in first ionisation energy values across the second period of the periodic table. **<u>4, 2</u>**

increasing nuclear charge //
decreasing atomic radius

first part correct...4, second part correct …2

(*ii*) Which element on your graph requires the most energy to form a mole of its monopositive ions? **<u>3</u>**

neon / (element with atomic number) 10 …3

(*iii*) Explain the peaks on your graph for the elements with atomic numbers 4 and 7. **<u>3</u>**

(electron configuration) of beryllium and nitrogen very stable /
due to half-filled outer subshell of nitrogen and filled outer subshell of beryllium …3
[if only one correct…(–1)]

(*c*) Plasma screen television sets like the one shown in Figure 17 emit light when a mixture of noble gases such as neon (Ne) and xenon (Xe) is ionised using high voltages. The resulting mixture of free electrons and positive ions is known as a plasma.

(*i*) Write the *s, p* electronic configuration of a neon atom. **<u>3</u>**

$1s^2\ 2s^2\ 2p^6$ ...3

(*ii*) Why is a lot of energy required to ionise a neon atom? **<u>6</u>**

neon is a noble or inert gas / neon has stable electronic configuration / full outer shell or eight electrons in outer shell / difficult to remove an electron …6

(*iii*) Explain why is the first ionisation energy of xenon less than that of neon. **<u>6</u>**

xenon has a larger atomic radius than neon /
(larger nuclear charge of xenon is cancelled) by the increased screening by inner electrons …6

(*d*) What is an atomic orbital? **<u>2×3</u>**

region in space (around the nucleus of an atom) …3
where the probability of finding an electron is high …3

How do the 2*p* atomic orbitals in neon differ from one another? **<u>3</u>**

orientation / direction in space / alignment along axes / have different magnetic quantum numbers / have different third quantum numbers / different orientation along axes drawn …3

State one difference between the 2*s* and a 2*p* atomic orbital of a neon atom. **<u>3</u>**

shape / energy …3

Question 9

Students were asked to prepare 250 cm^3 of a 0.08 M sodium carbonate solution from <u>anhydrous</u> sodium carbonate (Na_2CO_3), a primary standard.

(*a*) (*i*) Explain the underlined term. **<u>3</u>**

contains no water (of crystallisation) / dry or dried ...3

(*ii*) State two properties of a compound that would enable it to be used as a primary standard. **<u>4, 2</u>**

stable / pure / soluble / solid / high molecular mass / doesn't absorb water / doesn't lose water / not oxidised by air / can be weighed accurately

first correct…4, second correct …2

(*iii*) What mass of anhydrous sodium carbonate was required to prepare 250 cm^3 of the 0.08 M solution? **<u>2×3</u>**

$106 \times 0.08 = 8.48$ g // $106 \div 4 = 26.5$ ...3

$8.48 \div 4 = 2.12$ g // $26.5 \times 0.08 = 2.12$ g ...3

(*b*) Group A suggested making up the solution in container A and Group B selected container B as shown in Figure 18.

(*i*) Name containers A and B. **<u>4, 2</u>**

A = measuring cylinder / graduated cylinder //

B = volumetric flask

first correct…4, second correct …2

(*ii*) Explain why the use of container B would give a more accurate result. **<u>3</u>**

narrow neck (of the volumetric flask allows for more accurate measurement of volume) /

can be stoppered (to allow for mixing) /

calibrated more accurately ...3

(*c*) Describe the procedure the students of Group B followed in preparing their solution. **<u>6, 3×3</u>**

weigh out (2.12 g of anhydrous) sodium carbonate on a clock-glass /

add to a beaker containing (approx. 100 cm^3 of) deionised water /

stir to dissolve /

use a funnel to transfer (to the 250 cm^3 volumetric flask) /

add washings from beaker /

add deionised water to the flask until just below the mark /

use a dropper or wash bottle or dropwise (method) to add deionised water /

until the bottom of the meniscus rests on the mark / viewed at eye level /

(stopper) and invert several times

first correct …6, any other three ...3×3

(*d*) A number of 25 cm^3 portions of the sodium carbonate solution were titrated against a 0.20 M solution of nitric acid (HNO_3) according to the equation:

$$2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$$

(*i*) Explain why methyl orange would be suitable whereas phenolphthalein would be unsuitable as an indicator for this titration. **<u>3</u>**

strong acid weak base (titration) / phenolphthalein suitable for titration involving a strong base / changes colour in the correct pH range …3

(*ii*) Using methyl orange, what colour change occurred at the end point? **<u>2×3</u>**

yellow / orange to ...3

peach / pink / red ...3

[reversed 3 marks]

(*iii*) Calculate the volume of nitric acid required to neutralise 25.0 cm^3 of the sodium carbonate solution. **<u>3×3</u>**

$\frac{V_1 \times M_1}{n_1} = \frac{V_2 \times M_2}{n_2}$ ...3

$\frac{25 \times 0.08}{1} = \frac{V_2 \times 0.20}{2}$ ...3

$V_2 = \frac{25 \times 0.08 \times 20}{1 \times 0.2}$ = 20.(0)(cm^3) ...3

(*iv*) Calculate the pH of a 0.20 M nitric acid solution. **<u>6, 3</u>**

pH = –log[H$^+$] ...6

(pH = –log$_{10}$(0.20)) = 0.7 (0.69897 – 0.7) ...3

Question 10

(*a*) Define (*i*) reduction, **3**

gain (of electrons) …3

(*ii*) reducing agent, in terms of electron transfer. **3**

loses electrons …3

[Allow 'causes reduction' or 'is oxidised' …3]

Identify (*iii*) the substance reduced, (*iv*) the reducing agent in the following balanced equation. **2×3**

$$PbO + H_2 \rightarrow Pb + H_2O$$

reduced: PbO or Pb in PbO …3

reducing agent: hydrogen or H_2 …3

(*b*) Arrange the elements Fe, Pb, Mg and Cu in the order in which they occur in the electrochemical series. **6**

Mg, Fe, Pb and Cu …6

[reversed ….3, Mg first, Cu last …3]

Explain in terms of *the electrochemical series* why

(*i*) a plumber should not connect a copper pipe directly to an iron pipe but could use a plastic connector between them, **3**

iron is oxidised (at junction) more easily than copper / corrosion occurs (readily) at junction of two (dissimilar) metals / electrons can flow from the iron pipe to the copper pipe (causing corrosion) / plastic prevents electron flow or chemical reaction between the metals (so preventing corrosion) ...3

(*ii*) pieces of magnesium are sometimes attached to underground iron pipes, **3**

sacrificial anode / magnesium reacts or oxidises more easily or before iron / magnesium or Mg loses electrons more easily than iron or Fe / prevents corrosion of iron pipe / higher up in the ECS than iron …3

(*iii*) why it is unlikely that lead pipes would have to be replaced because of corrosion. **3**

lead not easily oxidised / lead does not lose electrons easily

[Allow lead replaced because of toxicity.] …3

(*c*) State *Faraday's first Law of electrolysis*. **2×3**

mass of an element liberated from or deposited on an electrode during electrolysis …3

is proportional to the quantity of electric charge or current (which passes through the electrolyte) ...3

(*d*) Figure 19 shows an apparatus used in the electrolysis of acidified water using inert electrodes.

(*i*) Name an acid suitable for acidifying the water. **3**

sulfuric acid / H_2SO_4 …3

(*ii*) Why is it necessary to acidify the water? **3**

water is not a good conductor of electricity / the acid improves conductivity …3

(*iii*) Which electrode, X or Y, is the anode? **3**

Y / right hand side …3

(*iv*) Name a material suitable for use as the inert electrodes. **3**

graphite / carbon / platinum …3

(*v*) At which electrode, X or Y, is oxygen gas formed, according to the following reaction? **3**

$$2H_2O \rightarrow O_2 + 4H^+ + \text{electrons}$$

Y / anode / right hand side …3

(*vi*) How many electrons are produced for every oxygen molecule produced in the reaction above? **<u>3</u>**
4 …3

If a current *I* was passed through acidified water for 15 minutes and a charge of 135 C was transferred, calculate

(*vii*) the current *I*, **<u>2×3</u>**
$Q = It$ / $I = Q \div t$ …3
$(I = 135 \div 900 \Rightarrow I =)$ 0.15 A ...3

(*viii*) the mass of oxygen gas released. **<u>3×3</u>**
$\frac{135}{96485.3383} = 0.0014$ …3
4 faradays release 32g of O_2 / 1 faraday releases 8 g of O_2 ...3
0.0014 faradays release 0.0112 g of O_2 [0.01 – 0.0112 g] ...3

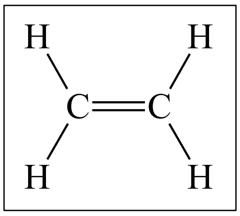
Question 11

(*a*) Bananas, harvested in the tropics and shipped green, are 'ripened' just before being placed on supermarket shelves by exposure to the gaseous <u>hydrocarbon</u> ethene (C_2H_4).
Ethene molecules are <u>unsaturated</u>.

(*i*) Explain the underlined terms. **<u>4×3</u>**
hydrocarbon: compound containing carbon and hydrogen …3
only …3

unsaturated: contains at least one double or triple bond …3
between 2 carbon atoms …3

(*ii*) Draw the structure of the ethene molecule. **<u>6</u>**



…6

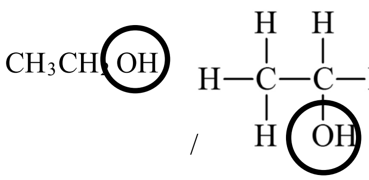
(*iii*) Name the homologous series to which ethene belongs. **<u>6</u>**
alkene(s) …6

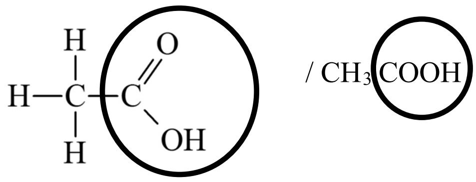
(*iv*) Ethene gas was prepared in the laboratory using the apparatus shown in Figure 20.
Identify the liquid held at X and solid Y. **<u>2×3</u>**
X = ethanol ...3
Y = aluminium oxide / Al_2O_3 …3

(*v*) Give one safety precaution observed during the experiment. **<u>6</u>**
avoid fire / avoid leak at stopper / avoid flame coming into contact with flammable reactant or product / avoid suckback (of cold water into hot test tube) / wear eye protection / tie back hair / wear gloves …6

(*vi*) Describe how a sample of ethene gas could be tested for unsaturation. **<u>3×3</u>**
bubble ethene through / to a stoppered test tube of ethene add …3
bromine water or bromine solution / add acidified potassium permanganate / …3
decolourises (is a positive test) / colour changes from (brown, red, orange, yellow, pink) to colourless …3

(*b*) (*i*) Draw the structures of an ethanol molecule and of an ethanoic acid molecule. **<u>2×3</u>**
(*ii*) Draw a circle around the functional group in each structure. **<u>2×3</u>**





correct ethanol structure …3
correct ethanoic acid structure …3
OH functional group of ethanol correctly circled …3
COOH functional group of ethanoic acid correctly circled …3

(*ii*) Classify, as a *dehydration*, an *oxidation* or a *reduction*, the conversion of wine to vinegar on exposure to air. In the process ethanol molecules are converted to ethanoic acid molecules. **<u>3</u>**
oxidation …3

(*c*) The smell associated with ripening strawberries is caused by a complex mixture of compounds including the ester shown in Figure 21.
Give the name of this ester. **<u>2×3</u>**
ethyl …3
methanoate / formate ...3

Question 12
Answer any three parts.

Question 12(*a*)

What term is used to describe the type of reaction in which heat is absorbed? **6**
endothermic …6

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H = -393.5 \text{ kJ mol}^{-1}$$
$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)} \qquad \Delta H = -285.8 \text{ kJ mol}^{-1}$$
$$6C_{(s)} + 6H_{2(g)} + 3O_{2(g)} \rightarrow C_6H_{12}O_{6(s)} \qquad \Delta H = -1271.0 \text{ kJ mol}^{-1}$$

Use the information above to calculate the energy change when one mole (180 g) of glucose ($C_6H_{12}O_6$) is made by plant photosynthesis according to the following balanced equation. **4×3**

$$6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(s)} + 6O_{2(g)}$$

reverse A and × 6:	$6CO_{2(g)} \rightarrow 6C_{(s)} + 6O_{2(g)}$	$\Delta H = 2361$ kJ	...3
reverse B and × 6:	$6H_2O_{(l)} \rightarrow 6H_{2(g)} + 3O_{2(g)}$	$\Delta H = 1714.8$ kJ	…3
C:	$6C_{(s)} + 6H_{2(g)} + 3O_{2(g)} \rightarrow C_6H_{12}O_{6(s)}$	$\Delta H = -1271.0$ kJ	…3
	$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$	$\Delta H = 2804.8 \text{ kJ mol}^{-1}$	…3

or

$$\Delta H_{\text{reaction}} = \Sigma\Delta H_{\text{f(products)}} - \Sigma\Delta H_{\text{f(reactants)}}$$
$$\Delta H_{\text{reaction}} = -1271.0 + O - (6 \times -393.5) - (6 \times -285.8)$$
$$\Delta H_{\text{reaction}} = -1271.0 + O + 2361 + 1714.8$$ …3×3
$$= 2804.8 \text{ kJ mol}^{-1}$$ …3

What mass of glucose is produced when 561 kJ of light energy is absorbed in this process? **2×2**
561 ÷ 2804.8 = 0.2 moles ...2
0.2 ×180 = 36 g ...2

Question 12(*b*)
In terms of Brønsted-Lowry theory
(*i*) define an acid, **6**
a proton donor …6

(*ii*) distinguish between a strong acid and a weak acid, **2×2**
strong acid is a good proton donor / fully dissociated …2
weak acid is a poor proton donor / slightly or weakly dissociated …2

(*iii*) explain a *conjugate acid-base pair*. **3**
two species that differ by a proton or H^+ …3

Identify a species acting as an acid in the following reaction. **3**

$$H_2O + HF \rightleftharpoons H_3O^+ + F^-$$

HF // H_3O^+ …3

What is the conjugate base of this acid? **3**
F^- / H_2O …3

Water may be described as amphoteric. Explain the underlined term. **3**
can donate or accept protons / can act as an acid and/or as a base / can react with acids or with bases …3

Question 12 (*c*)
The breathing equipment used by the rescue worker shown in Figure 22 contains potassium dioxide (KO_2) that acts as a source of oxygen and absorbs carbon dioxide as follows:

$$4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$$

(*i*) What volume of carbon dioxide at s.t.p. reacts with 0.8 moles of potassium dioxide? <u>2×3</u>

0.4 moles of CO_2 ...3
(0.4 × 22.4 =) 8.96 litres ...3

How many molecules of carbon dioxide are there in this volume? <u>4</u>

$(0.4 \times 6 \times 10^{23} =)\ 2.4 \times 10^{23}$ ...4

(*ii*) How many moles of oxygen are produced in the reaction of 0.8 moles of potassium dioxide? <u>2×3</u>

$KO_2 : O_2 = 4 : 3$ / 0.8 ÷ 4 = 0.2 ...3
(0.2 × 3 =) 0.6 (moles) ...3

What mass of K_2CO_3 is produced? <u>2×3</u>

$M_r = (39 \times 2) + 12 + (16 \times 3) = 138$ ...3
(138 × 0.4 =) 55.2 (g) ...3

Question 12(*d*)
The shape of a molecule is determined by the number of bonding pairs and the number of lone pairs of electrons in the valence shell of the central atom. These electron pairs take up positions to minimise repulsions between them.

(*i*) Why do electron pairs repel each other? <u>3</u>

like charges repel …3

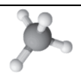
(*ii*) Compare the magnitude of the repulsion between two lone pairs and the repulsion between two bonding pairs of electrons. <u>2</u>

repulsion between two lone pairs is greater than repulsion between two bonding pairs of electrons …2

Account for this difference in the magnitude of the repulsions. <u>2</u>

one pairs are closer (to nucleus) and to one another (than bond pairs) …2

(*iii*) Supply the pieces of information A to E omitted from the columns of the table below. <u>5×3</u>

Arrangement	Shape	No. lone pairs	No. bonding pairs	Bond angle	Example
	**A**	2	2	104.5°	**H_2O**
	pyramidal	**B**	3	**C**	**NH_3**
	**D**	0	**E**	109.5°	**CH_4**

A = v-shape, planar or bent …3
B = 1 …3
C = 107° …3
D = tetrahedral …3
E = 4 …3
[107.5°…(–1)]

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