Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2022

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.

Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION

PHYSICS AND CHEMISTRY – HIGHER LEVEL

General Guidelines

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

1. In many instances only key words are given, i.e. 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, 1 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

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 330 @ 10%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 330 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 247 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
248 - 250	24
251 - 253	23
254 - 256	22
257 - 260	21
261 - 263	20
264 - 266	19
267 - 270	18
271 - 273	17
274 - 276	16
277 - 280	15
281 - 283	14
284 - 286	13
287 - 290	12

Bunmharc	Marc Bónais
291 - 293	11
294 - 296	10
297 - 300	9
301 - 303	8
304 - 306	7
307 - 310	6
311 - 313	5
314 - 316	4
317 - 320	3
321 - 323	2
324 - 326	1
327 - 330	0

QUESTION 1
Any eleven parts **11×6**

(*a*) Is displacement an example of a vector?
Give a reason for your answer. **2×3**
yes …3
has direction / distance is the scalar component of displacement …3

(*b*) In April 2021 the tiny Mars helicopter *Ingenuity*, shown in Figure 1, became the first aircraft to make a powered controlled flight on a planet other than Earth. The mass of Ingenuity on Earth is 1.80 kg. The acceleration due to gravity on the surface of Mars is 3.72 m s^{-2}. What is
(*i*) the mass,
(*ii*) the weight, of Ingenuity on the surface of Mars? **2×3**
1.80 (kg) …3
1.80 × 3.72 = 6.696 or 6.7 kg (N) …3

(*c*) What is a force? **6**
causes (or tends to cause) acceleration (motion) or change of direction or change of shape or changes an existing motion in magnitude or direction …6
or
[Allow ….6 for push or pull or interaction between two objects or causes reaction or (*F* =) *m* x *a*]

(*d*) Two satellites are in stable orbit around the Earth at the same distance from its centre but the Earth's gravitational force on one satellite is twice that on the other. Explain. **2×3, 6**
$F = G\frac{M_1M_2}{d^2}$ / $F = G\frac{M_eM_1}{d^2}$ / $W = mg$ …3
($2F = G\frac{M_eM_2}{d^2} \Rightarrow$) $m_2 = 2m_1$ // ($2W = Mg \Rightarrow$) $m_2 = 2m_1$ …3
or
one satellite twice mass or weight of the other …6
[different mass or weight (–1)]

(*e*) What is meant by the triple point temperature of water? **6**
steam or water vapour, (liquid) water and ice co-exist / three states of water present at same time …6
[0.01 °C or 273.16 K …(6)]

(*f*) The resistance of a piece of wire is 110.0 Ω at 0 °C and 150.0 Ω at 100 °C
Calculate the temperature in °C when the resistance of the wire is 132.8 Ω. **5, 1**
$(t =)\frac{x_t - x_0}{x_{100} - x_0} \times 100$ / $(t =)\frac{132.8 - 110.0}{150.0 - 110.0} \times 100$ …5
(t =) 57 (°C) …1

(*g*) State Boyle's law. **2×3**
pressure is inversely proportional // $p \propto$ // pV …3
to volume for a fixed mass of gas at constant temperature //
1/V for a fixed mass of gas at constant temperature //
constant or k for a fixed mass of gas at constant temperature …3
[*Either* fixed mass of gas *or* constant temperature omitted (–1)]

(*h*) Figure 2 represents plane water waves approaching a gap. State and explain what happens, if anything, to the frequency of the wave as it passes through the gap. **2×3**

no change …3

frequency determined by source / neither wavelength nor speed change ..3

(*i*) What type of electromagnetic radiation can be detected

(*i*) using a blackened thermometer bulb,

infra-red

(*ii*) using fluorescent material? **5, 1**

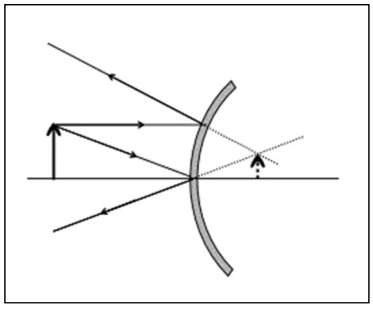
ultraviolet / x-ray / gamma

first correct …5, second correct …1

(*j*) Draw a ray diagram to show the formation of an image in a convex mirror. **2×3**

2 rays reflected correctly in front of mirror …3

virtual path behind mirror of 2 rays to give upright, diminished image …3



[Two rays drawn correctly drawn (showing image formation) by concave mirror or convex lens …3]

(*k*) Why does dispersion occur when a beam of white light passes through a prism? **2×3**

(in prism) each colour …3

has unique speed or wavelength or refractive index / refracted by different amount …3

(*l*) State Coulomb's law of force between two charges. **2×3 or 6**

force between two (point) charges is proportional to the product of the charges / $F \propto Q_1Q_2$ …3

and inversely proportional to the square of the distance separating them / $F \propto 1/d^2$ …3

or

$F \propto \frac{q_1q_2}{d^2}$ or $F = \frac{1}{4\pi\epsilon}\frac{q_1q_2}{d^2}$ …6

[$F = \frac{q_1q_2}{d^2}$ …(–1)]

(*m*) Identify two factors that affect the capacitance of a parallel-plate capacitor. **4, 2 or 6**

(common) area of plates or *A* / separation of plates or *d* / medium or permittivity or ε or material between plates

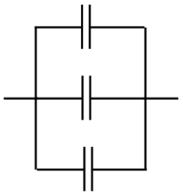
first correct …4, second correct …2

or

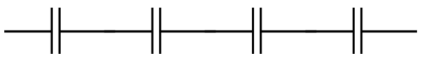
$C = \frac{\varepsilon A}{d}$ / $C \propto \frac{\varepsilon A}{d}$ …6

(*n*) Four 20 µF capacitors are available. Draw diagrams to show how some or all the capacitors could be connected to produce a combined capacitance of (*i*) 60 µF, (*ii*) 5 µF. **5, 1**

three (20 µF) connected in parallel (= 60 µF) /



four (20 µF) connected in parallel (= 5 µF) /



first correct …5, second correct …1

(*o*) How is a moving-coil galvanometer be modified for use as a voltmeter? **2×3**

(large) resistance / multiplier ...3

connected in series …3

(*p*) A current carrying wire lying on a table between two bar magnets of equal strength as shown in Figure 3 experiences an upwards force. Is A a north pole or a south pole? **6**

south …6

(*q*) What is meant by nuclear fusion? **2×3**

joining together of (two small) nuclei (to form a larger nucleus) …3

with release of energy …3

(*r*) The energy released in a nuclear reaction is 1.8×10^{-12} J. Calculate the loss in mass in kg. **5, 1**

$E = mc^2$ / (E =) $m \times (3 \times 10^8)^2$ / $(1.8 \times 10^{-12} =) m \times (3 \times 10^8)^2$ …5

(E =) 2.0×10^{-29} (kg) …1

QUESTION 2

(*a*) State the principle of conservation of energy. **9**

energy is neither created nor destroyed but can be converted from one form into another …9

[Allow $E_k + E_p$ = constant …9][Allow $\Delta E_k + \Delta E_p = 0$ …9]

['but can be converted from one form into another' omitted (–3)]

Distinguish between kinetic energy and potential energy. **2×3**

kinetic energy: energy due to motion / $\frac{1}{2}mv^2$ …3

potential energy: energy due to position or condition / stored energy / mgh …3

Define the S.I. unit of energy, the joule. **3**

one newton or 1 N causes movement through one metre (in direction of force) /
one newton or 1 N causes point of application of force to move 1 m …3

[Allow …3 for definition of work, i.e. 'force × displacement' or 'force × distance' or Fs or Fd]

(*b*) State Newton's first law of motion. **2×3**

object remains (at rest or) at constant velocity …3

unless acted on by a force …3

[speed instead of velocity …(–1)]

(*c*) Figure 4 shows a vertical cross section through part of a skateboard park. A small ball of mass 0.40 kg, with an initial speed *u* parallel to AB at the point A, moved from A to E staying in contact with the skateboard surface throughout and without losing any energy to friction.

The ball travelled 1.25 m from A to B with constant acceleration of 8.0 m s^{-2} in 0.25 s.
Find

(*i*) the initial speed *u* of the ball at A, **5, 1**

$s = ut + \frac{1}{2}at^2$ / $1.25 = u(0.25) + \frac{1}{2}(8.0)(0.25)^2$ …5

($0.25u = 1.25 - 0.25 = 1.0 \Rightarrow u = 1.0 \div 0.25 =$) 4.0 or 4 m s^{-1} …1

[no unit or incorrect unit …. (–1)]

(*ii*) the speed of the ball at B, **5, 1**

$v = u + at$ or $v = 4.0 + 8.0 \times 0.25$ / $v^2 = u^2 + 2as$ or $v^2 = 16.0 + 2 \times 8.0 \times 1.25 = 36.0$ / $s = \frac{1}{2}(u + v)\,t$
or $1.25 = \frac{1}{2}(4 + v)\,0.25$ …5

($\Rightarrow v =$) 6.0 or 6 m s^{-1} …1

[no unit or incorrect unit …. (–1)]

(*iii*) the kinetic energy of the ball at B. **5, 1**

(E_K at B =) $\frac{1}{2}\,mv^2$ or ($0.5 \times 0.40 \times 36$) …5

= 7.2 J …1

[no unit or incorrect unit …. (–1)]

B is 0.5 m above C.

(*iv*) Use the principle of conservation of energy to calculate the potential energy converted to kinetic energy as the ball rolled from B to C. **2, 1**

mgh / $0.40 \times 9.8 \times 0.50$ …2

= 1.96 – 2 J …1

[no unit or incorrect unit …. (–1)* but penalise once only in (*iii*), (*iv*) and (*v*)]

(*v*) What was the total kinetic energy of the ball when it reached C? **3**

(E_K at C = 7.2 + 1.96 =) 9.16 – 9.2 J …3

[no unit or incorrect unit …. (–1)* but penalise once only in (*iii*), (*iv*) and (*v*)]

The ball had a constant horizontal speed as it moved from C to D.

(*vi*) Is there a horizontal force on the ball between C and D? Explain your answer. **2×3**

no …3

Newton's first law / no external (horizontal force) / no friction …3

(*vii*) Is there a vertical force on the ball between C and D? Explain your answer. **2×3**

no // yes …3

forces cancel / two forces / no net force / gravitational or gravity force cancelled by reaction force // gravity or gravitational or reaction force …3

The ball came to rest for an instant at E where it reached its maximum height.

(*viii*) Calculate the height of E above D. **5, 1**

mgh = 9.16 or 0.40 × 9.8 × h = 9.16 …5

($\Rightarrow h$ =) 2.3 m …1

[no unit or incorrect unit …. (–1)]

QUESTION 3

(*a*) (*i*) State the laws of refraction of light. **3, 6**

incident ray, refracted ray and normal in the same plane
[reflection instead of refraction …(–3)]

and

$\frac{sini}{sinr}$ = constant or *n* or *k* or μ
or
sine of angle of incidence proportional to sine angle of refraction /
sin*i* ∝ sin*r*
[reflection instead of refraction …(–3) but once only in (*i*)][sines omitted (–3)]
first correct …6, second correct …3

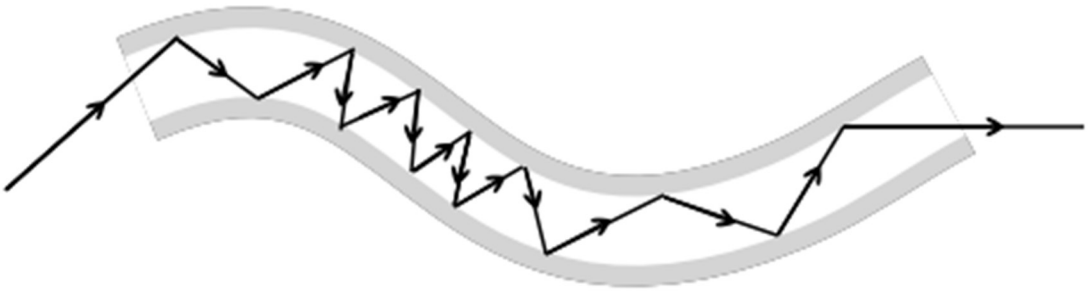
(*ii*) State the two conditions necessary for total internal reflection of light to occur. **5, 1**

light travelling from a more dense to a less dense medium
the angle of incidence greater than the critical angle
first correct …5, second correct …1

(*iii*) What is meant by the critical angle of a material? **2×3**

angle of incidence (in the denser medium) …3
when the angle of refraction is 90° / beyond which rays are totally reflected (at boundary) …3

(*iv*) Sketch a diagram to show how a beam of laser light can travel along an optic fibre by means of total internal reflection. **3**



ray zig-zagging along confined in a tube or fibre bent or otherwise (with less dense cladding and more dense core) …3
[arrows not essential]

(*b*) The table gives the values of the critical angle (*c*) for a number of solid materials with different refractive indices (*n*).

n	**1.1**	**1.3**	**1.5**	**1.7**	**2.2**	**2.4**	**2.7**
***c* (°)**	**65**	**50**	**42**	**36**	**27**	**25**	**22**

(*i*) Plot a graph of *n* versus $\frac{1}{sinc}$ to show that *n* and sin*c* are inversely proportional. **6×3**

n	**1.1**	**1.3**	**1.5**	**1.7**	**2.2**	**2.4**	**2.7**
***c* (°)**	**65**	**50**	**42**	**36**	**27**	**25**	**22**
sin*c*	0.9063	0.766	0.6691	0.59	0.4539	0.4226	0.3746
1/sin*c*	1.103387	1.305483	1.494545	1.701259	2.203128	2.366304	2.669514

sinc or 1/sin*c* correctly calculated and rounded …3
axes labelled *n* and 1/sin*c* or sin*c* and 1/*n* …3
axes drawn with appropriate scales …3
seven points correctly plotted …3
points connected …3
straight line through origin ...3
[If not on graph paper (–3)][Max mark (9) for *n* versus *c*]
[Max 9 for graph using sines of radians from (*i*) above]

(*ii*) Use your graph to find the value of *k* in the equation $n = k\frac{1}{\sin c}$. **6**
(*k* =) 0.9 – 1 …6
[no work need be shown; *k* may be obtained from work on the slope or otherwise]

(*iii*) What is the refractive index of a gemstone that has a critical angle of 30°? **5, 1**
$n = \frac{1}{sinc}$ or $n = \frac{1}{sin30}$ or $n = \frac{1}{0.5}$ …5
($\Rightarrow n$ =) 2 …1
[Treat as slip error (–1) use of radians instead of degrees.]

(*c*) When an object of height 5.0 cm was placed in front of a converging (convex) lens a real inverted image of height 2.5 cm was formed on the other side of the lens. The distance between the object and its image was 45 cm.

(*i*) How far from the lens was the object placed? **5, 1**
m = *v*/*u* / 0.5 = *v*/*u* or *u* = 2*v* and 45 = *u* + *v* …5
(45 = 3*v* $\Rightarrow$ *u* =) 30 cm …1

(*ii*) Calculate the focal length of the lens. **5, 1**
$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} / \frac{1}{f} = \frac{1}{30} + \frac{1}{15}$ …5
($\Rightarrow \frac{1}{f} = \frac{3}{30}$ and *f* =) 10.0 cm …1
[no unit or incorrect unit …. (–1)]
[Drawing to scale acceptable.]

QUESTION 4

(*a*) (*i*) What is meant by the term *ideal gas*? **2×3**

obeys gas laws or Boyle's law or kinetic theory …3

at all temperatures and pressures or at all conditions …3

[(–1) if temperature or pressure omitted]

(*ii*) State two assumptions of the kinetic theory of gases. **2×3**

gases contain large number of particles or molecules / in rapid motion / in random motion / in straight line motion / collisions occur between particles or molecules / collisions occur with walls of container / collisions elastic or involve neither loss nor gain of energy / negligible volume occupied by particles or molecules / negligible duration of collisions / no forces (between particles except during collisions), etc

any two…2×3

(*iii*) What property of a gas is related to the average kinetic energy of its particles? **3**

temperature / T …3

(*b*) Under a microscope it was observed that tiny pollen grains suspended in water moved in an irregular zig-zag manner.

(*i*) What name is given to this irregular movement? **6**

Brownian (motion or movement) …6

(*ii*) What is the explanation for the irregular movement? **3**

pollen grains collide with water molecules / particles in constant or random motion …3

(*iii*) What is the significance of this observation? **3**

evidence for kinetic theory / evidence for particles / evidence for nature of matter …3

(*c*) The data in the table below shows the product of the pressure and the volume (*pV*) of a fixed mass of H_2 gas at a number of different absolute temperature (*T*) values.

***T* (K)**	**100**	**150**	**200**	**250**	**300**	**350**	**400**
***pV* (J)**	**29.1**	**44.0**	**58.2**	**72.7**	**86.4**	**101.8**	**116.3**

(*i*) Justify why *pV* can be measured in joules. **3**

$pV = nRT \Rightarrow$ mol × J K^{-1} mol^{-1} × K $\Rightarrow$ ~~mol~~ × J ~~K^{-1}~~ ~~mol^{-1}~~ × ~~K~~ = J /

$pV \Rightarrow$ Pa × m^3 = N m^{-2} × m^3 $\Rightarrow$ N m = J /

$pV = F/A \times V$ = $N/m^2 \times m^3$ = N m = J …3

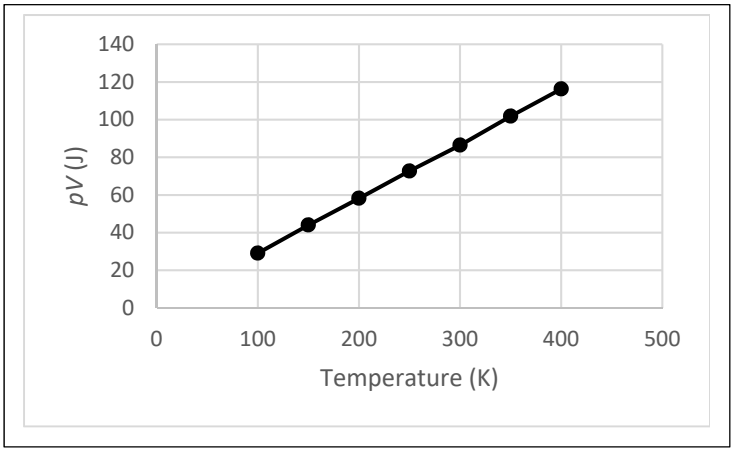
[Allow *pV* is equivalent to work or energy …3]

(*ii*) It not possible to get a *pV* measurement for hydrogen at 0 K. Explain. **9**

gas condenses before it cools to 0 K / absolute zero theoretical / in theory gas has zero volume at 0 K / no refrigeration device cools to this temperature / cannot reach 0 K or absolute zero, etc …9

(*iii*) Plot a graph of *pV* versus *T* for the H_2 gas. **6×3**

axes labelled *pV* or N m and *T* or temperature or K …2×3
axes drawn with appropriate scales …3
any four points correctly plotted …3
remaining points correctly plotted …3
points joined ...3
[If not on graph paper (–3)]
[Axes reversed acceptable.]



(*iv*) Use the slope of your graph to find the number of moles of H_2 gas present. **4, 1, 1**

pV on y axis $\Rightarrow \frac{y_2-y_1}{x_2-x_1} = \frac{116.3-29.1}{400-100} / \frac{\text{rise}}{\text{run}} = \frac{116.3-29.1}{400-100}$ …4
(slope =) 0.29 ...1
n = slope ÷ $R \Rightarrow n$ = 0.035 (moles) [0.033 – 0.037 (moles)] …1

or

pV on *x* axis $\Rightarrow \frac{y_2-y_1}{x_2-x_1} = \frac{400-100}{116.3-29.1} / \frac{\text{rise}}{\text{run}} = \frac{400-100}{116.3-29.1}$ …4
(slope =) 3.45 ...1
(n = 1/(slope × R) $\Rightarrow n$ = 1 / (3.45 × R)=) 0.035 (moles) [0.033 – 0.037 (moles)] …1

(*v*) How would the slope of the graph be affected if an equal mass of helium (He) gas was used instead of hydrogen gas? **3**

pV on y axis $\Rightarrow$ smaller / slope H_2 bigger / slope H_2 double that of He / He slope half the H_2 slope/ slope He graph = 0.15 (J K^{-1}) …3
or
pV on *x* axis $\Rightarrow$ bigger / slope H_2 smaller / slope H_2 half that of He / He slope double the H_2 slope/ slope He graph = 6.9 (J K^{-1}) …3

[Allow …3 for more moles of H_2 / half number of moles He compared to H_2 / 0.072 g H_2 in 0.036 moles $\Rightarrow$ 0.018 moles He]

QUESTION 5

(*a*) (*i*) What is an electric current?

flow or movement of electrons or charged particles or ions or charge

(*ii*) What is meant by the potential difference between two points in an electrical field? 6, 3

work done when a (positive) charge of one coloumb or 1 C or a unit of (positive) charge is moved between the points / energy involved when moving a (positive) charge of one coloumb or 1 C or a unit of (positive) charge between the points / $W \div Q$

first correct…6, second correct….3

(*b*) (*i*) State Ohm's law. 2×3

current (in a conductor) proportional // $I \propto$ // voltage or potential difference proportional // $V \propto$ // $V =$ …3
to potential difference or voltage at constant temperature // *V* at constant temperature //
to *I* at constant temperature // current (in a conductor) at constant temperature // *IR* at constant temperature …3
[at constant temperature omitted …. (–1)]

(*ii*) Figure 5 shows a circuit, used to verify Ohm's law for conductor X, with three essential components missing.
Copy this circuit and complete it in your answerbook to include the missing components. 3×3

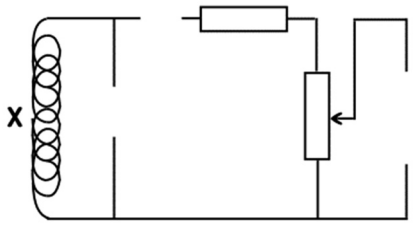


Figure 5

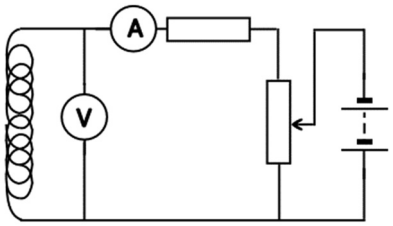
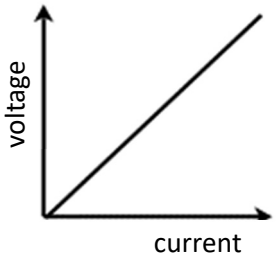


Figure 5 completed

battery / power supply …3
voltmeter across X …3
(milli)ammeter or galvanometer …3

(*iii*) In the case of conductor X obeying Ohm's law, sketch the graph you would expect to obtain with data provided using the completed circuit. 2×3

axes labelled *V* or voltage or potential difference or volts or V and *I* or current or amps or A …3
straight line through origin …3



(*c*) Consider the circuits shown in Figure 6 and Figure 7 each of which contains twelve identical 14.4 Ω resistors, a 12.0 V battery and a switch that automatically opens the circuit 600 s after it is switched on. The total resistance of the connecting wires, battery and switch is negligible in each circuit.

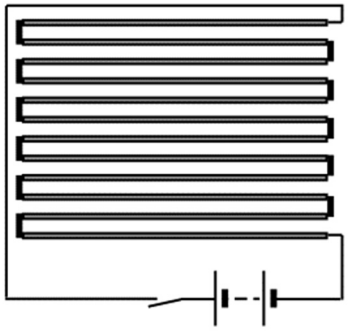


Figure 6

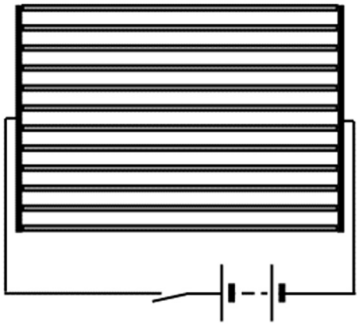


Figure 7

In the case of the circuit in Figure 6, calculate

(*i*) the total resistance in the circuit, **3**

$14.4 \times 12 = 172.8\ \Omega$ …3

[no unit or incorrect unit …. (–1)* but penalise once only in (*i*) and (*iv*)]

(*ii*) the current through the resistors when the switch is closed, **5, 1**

$V = IR$ / $12 = I \times 172.8$ …5

$\Rightarrow (I =)\ 12 \div 172.8 = 5/72 = 0.0694 – 0.07$ A or amps …1

[no unit or incorrect unit …. (–1)** but penalise once only in (*ii*) and (*v*)]

(*iii*) the energy converted to heat in *one* of the resistors in 600 s. **5, 1**

$E = VIt$ / $1 \times 0.0694 \times 600$ or $(12 \times 0.0694 \times 600) \div 12$ / $E = RI^2t$ / $14.4 \times (0.0694)^2 \times 600$ or $(172.8 \times (0.0694)^2 \times 600) \div 12$ …5

$\Rightarrow (E =)$ 41.7 J or joules …1

[Allow energy in circuit 500 J …5 if no other marks awarded]

[no unit or incorrect unit …. (–1)*** but penalise once only in (*iii*) and (*vi*)]

In the case of the circuit in Figure 7, calculate

(*iv*) the total resistance of this arrangement of resistors, **5, 1**

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} (+ \ldots. + \frac{1}{R_{12}})$ / $\frac{1}{R} = \frac{12}{14.4}$ …5

$\Rightarrow R = \frac{14.4}{12} = \frac{6}{5} = 1.2\ \Omega$ …1

[no unit or incorrect unit …. (–1)* but penalise once only in (*i*) and (*iv*)]

(*v*) the current through one of the resistors when the switch is closed, **2, 1**

$V = IR$ / $12 = I \times 14.4$ …2

$\Rightarrow (I =)\ 12 \div 14.4 =) 5/6$ or 0.83333 A or amps …1

[no unit or incorrect unit …. (–1)** but penalise once only in (*ii*) and (*v*)]

(*vi*) the energy converted to heat in *one* of the resistors in 600 s. **5, 1**

$E = VIt$ or $12 \times 0.833 \times 600$ or $(12 \times (12 \times 0.833) \times 600) \div 12$ or $E = RI^2t = 14.4 \times (0.833)^2 \times 600$ or $(1.2 \times (8.33)^2 \times 600) \div 12$ …5

$\Rightarrow (E =)$ 6000 J or joules …1

[Allow energy in circuit 72,000 J …5 if no other marks awarded]

[no unit or incorrect unit …. (–1)*** but penalise once only in (*iii*) and (*vi*)]

(*d*) The circuits in (*c*) could be used as vehicle rear-window demisters to remove condensation from the inside surface of the window or to melt frost on the outside.

Which circuit do you think would be more suitable for use in this way? **1**

first or Figure 6 or one on left // second or Figure 7 or one on right …1

Give a reason for your answer. **5**

less heat generated / less likely to crack glass or safer because of heating or safer because current smaller //
more heat (per resistor) or larger current or more effective or demists faster or defrosts faster /
if (partially) damaged can still get hot …5

QUESTION 6

Answer any two parts.

Question 6 (*a*)

In an experiment to verify the principle of conservation of momentum, A, of mass 180 g, was set in motion with constant velocity and was allowed to collide with a second stationary B of mass 198 g. After the collision A and B moved together with constant velocity. A travelled 42 cm in 0.35 s before colliding with B. Together A and B travelled 20 cm in 0.35 s after the collision in the same direction as A was originally moving.

(*i*) Draw a labelled diagram of an arrangement of apparatus suitable for this investigation. **2×3**

trolleys on sloped track or gliders on horizontal air track and device to join trolleys or gliders …3

(timing using) ticker tape, light gates, Fletcher's trolley, datalogging sensor (and computer), timer, etc …3

[Device to join trolleys or gliders omitted (–1)]

(*ii*) State the principle of conservation of momentum. **2×3**

when no external force acts or in a closed system (total) momentum before a collision equals //
when no external force acts or in a closed system (total) momentum remains or is //
when no external force acts or in a closed system $m_1u_1 + m_2u_2$ = …3

momentum after // constant // $m_1v_1 + m_2v_2$ or $(m_1 + m_2)v$ …3

[external force or closed system omitted …(–1)]

(*iii*) Calculate the velocity of A before the collision. **5, 1**

$v = \frac{d}{t} = \frac{42}{0.35} = \frac{0.42}{0.35}$ …5

(v =) 120 cm s^{-1} or 1.2(0) m s^{-1} …1

[no unit or incorrect unit …. (–1)]

(*iv*) Calculate the momentum of A and B travelling together after the collision. **5, 3, 1**

($v = \frac{d}{t} = \frac{20}{0.35}$ or $\frac{0.20}{0.35}$) = 57.1(4) or $\frac{400}{7}$ (cm s^{-1}) or 0.571(4) or $\frac{4}{7}$ (m s^{-1}) …5

mv = (180 + 198) × 57.1(4) or (180 + 198) × 0.571(4) …3

= 21600 g cm s^{-1} or 21.6 kg cm s^{-1} or 0.216 kg m s^{-1} …1

[no unit or incorrect unit …. (–1)]

(*v*) Explain whether the data verifies the principle of conservation of momentum. **5, 1**

yes / momentum before = momentum after / initial momentum A = final momentum A and B /
momentum unchanged by collision / $m_1u_1 + m_2u_2 = (m_1 + m_2)v$ …5

(mv = 180 × 120 =) 21600 g cm s^{-1} or (0.180 × 1.2 =) 21.6 kg cm s^{-1} or (0.18 × 0.12 =) 0.216 kg m s^{-1} …1

[Allow …5 for no / momentum before ≠ momentum after / initial momentum A ≠ final momentum A and B / momentum changed by collision if slip(s) in mathematical work result(s) in candidate answer in part (*iii*) ≠ total initial momentum calculated in (*v*)]

Question 6 (*b*)

Figure 8 shows a beam of monochromatic visible light striking a pair of narrow slits. After passing through the slits the light then strikes a screen.

(*i*) Name the two phenomena that occur when the light passes through the slits. **6, 5, 1**

interference

diffraction

(*ii*) What do these phenomena tell us about the nature of light?

(behaves as a) wave / (has) wave (properties)

first correct …6, second correct…5, third correct …1

When electromagnetic radiation of a certain frequency falls on a freshly sanded zinc plate placed on the cap of a negatively charged gold foil electroscope, the leaves collapse.

(*iii*) What phenomenon occurs when the radiation strikes the zinc plate? **6**

photoelectric effect / release of electrons from surface of metal or zinc …6

(*iv*) Explain why visible light does not cause the leaves to collapse but ultraviolet light does. **3**

photons of uv have enough energy / uv frequency high enough /

visible photons do not have enough energy / visible frequency too low …3

(*v*) Calculate the energy of a photon of electromagnetic radiation from a source that has a wavelength of 1.5×10^{-7} m. **2×5, 2×1 or 10, 2**

$c = f\lambda \Rightarrow f = \frac{c}{\lambda} = \frac{3\times10^{8}}{1.5\times10^{-7}}$ …5

(f =) 2×10^{15} Hz …1

$E = hf$ / $E = 6.626 \times 10^{-34} \times 2 \times 10^{15}$ …5

(E =) $1.25 \times 10^{-18} - 1.33 \times 10^{-18}$ J …1

[no unit or incorrect unit …(−1)]

or

$E = h\frac{c}{\lambda}$ / $E = 6.626 \times 10^{-34}(\frac{3\times10^{8}}{1.5\times10^{-7}})$ …10

(E =) $1.25 \times 10^{-18} - 1.33 \times 10^{-18}$ J …2

[no unit or incorrect unit …(−1)]

Question 6 (*c*)

(*i*) What is meant by electromagnetic induction? **2×3**

an emf produced in coil or current (flow) in coil results // E = // $E \propto$ ...3

due to change in the magnetic flux linking or through coil // $-N\frac{d\emptyset}{dt}$ // $-\frac{d\emptyset}{dt}$ or $\frac{d\emptyset}{dt}$ ...3

(*ii*) Describe a simple demonstration of electromagnetic induction. **2×3**

method of changing magnetic flux linking a coil by relative motion between coil and magnet or varying magnetic field ...3

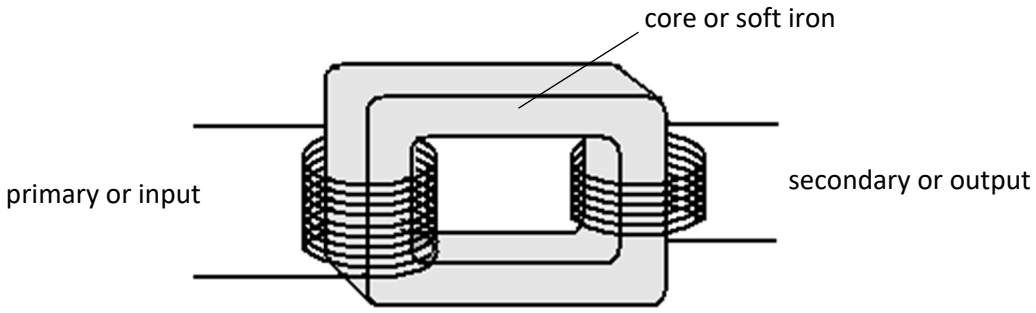
method of detecting or observing induced emf or current ...3

(*iii*) Describe with the aid of a labelled diagram how a step-down transformer works. **3×3**

ac in primary stated or labelled / ac induced in secondary stated ...3

more coils in primary stated or shown / emf in secondary less stated ...3

core or soft iron links primary and secondary coils stated or drawn ...3



A transformer with 250 turns in its primary coil converts 230 V a.c. to 46 V a.c.

(*iv*) How many turns are there in the secondary coil of this transformer? **5, 1**

$\frac{V_p}{V_s} = \frac{N_p}{N_s}$ / $\frac{230}{46} = \frac{250}{N_s}$ ...5

$\Rightarrow$ 50 ...1

(*v*) If the current in the secondary coil is 12.5 A, find the current in the primary coil assuming no power loss. **5, 1**

($P_{in} = P_{out} \Rightarrow$) $V_{in}I_{in} = V_{out}I_{out}$ / 230 × I_{in} = 46 × 12.5 // ratio of turns primary to secondary turns = 5:1 ...5

(I_{in}) = 2.5 (A) ...1

Question 6 (*d*)

An ionising smoke alarm uses a small quantity of a certain radioactive isotope as a source of alpha particles.

(*i*) What is radioactivity? **2×3**

(spontaneous) decay of unstable nucleus or nuclei …3

with the emission of radiation / with the emission of alpha, beta or gamma rays …3

(*ii*) In terms of subatomic particles, what is an alpha particle? **3**

two protons and two neutrons / 2p + 2n …3

[helium nucleus or He^{2+} or $\frac{4}{2}\mathrm{He}$ …(–1)]

(*iii*) Identify the isotope used in the smoke alarm that produces neptunium–237 nuclei by alpha decay. **2×3**

americium or Am or (*Z* =) 95 …3

241 …3

(*iv*) Suggest why an alpha-particle source is more suitable for use in a domestic smoke alarm than either a beta-particle source or a gamma-ray source. **6**

alpha less penetrating or beta or gamma more penetrating / alpha won't leak out …6

[alpha safer …6]

(*vi*) Define the half-life of a radioactive isotope. **9**

time taken for half of (radioactive) sample to decay / time taken for activity to fall to half / time taken for half the nuclei to decay …9

[Allow 9 marks for $T_{\frac{1}{2}} = \frac{ln2}{\lambda}$]

(*vii*) 6.25% of the radioactive isotope used in a smoke alarm will remain undecayed 1728 years after its manufacture. What is the half-life of the radioactive isotope? **3**

$100 \rightarrow 50 \rightarrow 25 \rightarrow 12.5 \rightarrow 6.25$ / 4 half-lives $\Rightarrow$ 1728 ÷ 4 = 432 (years) …3

QUESTION 7

Any eleven parts **11×6**

(*a*) How many (*i*) neutrons, (*ii*) electrons, does the dipositive ion of a calcium–40 atom have? **5, 1**

20 (neutrons)
18 (electrons)

first correct …5, second correct …1

(*b*) Define relative atomic mass. **2×3**

average mass of an atom (of the element) /
average mass of isotopes (of the element) taking abundances into account or as they occur naturally /
average of mass numbers of isotopes (of the element) taking abundances into account or as they occur naturally …3

compared to or based on (1/12th) of carbon–12 isotope …3

(*c*) What is the atomic number of an atom that has 10 neutrons and a mass number of 19?
Is this atom an isotope of the element oxygen? **5, 1**

9 / $^{19}_{9}X$ / $_{19}^{9}X$
no
[Allow F or fluorine for atomic number]

first correct …5, second correct …1

(*d*) How many lone pairs of electrons are present in the valence shell of the central atom in a molecule of (*i*) H_2O
(*ii*) NH_3? **5, 1**

two / 2
one / 1

first correct …5, second correct …1

(*e*) An instant coffee contains 5×10^{-4} moles of caffeine ($C_8H_{10}N_4O_2$) per spoonful of granules. See Figure 9. How many nitrogen atoms are there in the caffeine in one spoonful of these coffee granules? **5, 1**

2×10^{-3} (moles N per spoonful) / $5 \times 10^{-4} \times 4$
$2 \times 10^{-3} \times 6 \times 10^{23} = 1.2 \times 10^{21}$ (N atoms)

first correct step …5, second correct …1

(*f*) What are allotropes?
Give an example. **5, 1**

different (physical) forms of the same element
example of (at least) two forms of carbon, sulfur, phosphorus, oxygen, etc

first correct …5, second correct …1

(*g*) A molecule of H_2S has an overall dipole moment but a BeH_2 molecule does not.
Account for this difference. **6**

H_2S: (two) lone pairs / centres of negative and positive charge do not coincide or do not cancel /
vector sum of individual dipoles not zero / valence electron pairs or bonds not linear or arranged in a v /
distribution or arrangement of polar bonds around sulfur or around central atom has insufficient symmetry /

BeH_2: no lone pairs / centres of negative and positive charge coincide or cancel / vector sum of individual dipoles zero / valence electron pairs or bonds linear / distribution or arrangement of polar bonds around beryllium or around central atom has sufficient symmetry …6

(*h*) Write the chemical formulae for copper(I) oxide and iron(II) sulfate. **5, 1**

Cu_2O

$FeSO_4$

first correct …5, second correct …1

(*i*) Write a balanced equation for the reaction between sodium hydride and water. **2×3**

$NaH + H_2O \rightarrow NaOH + H_2$ formulae…3

balancing …3

(*j*) Identify (i) an acidic oxide of sulfur,

(*ii*) a basic compound of hydrogen and a non-metallic element. **5, 1**

SO_2 or sulfur dioxide or sulfur(IV) oxide or SO_3 or sulfur trioxide or sulfur(VI) oxide

NH_3 or ammonia or any other Group 15 hydride

first correct …5, second correct …1

(*k*) Hydrogen and oxygen gases are produced by the electrolysis of acidified water in a voltameter like that shown in Figure 10. What is the ratio of H_2 to O_2 produced

(*i*) by volume

(*ii*) by mass? **5, 1**

2 to 1 / 2 : 1 / 2/1

1 to 8 / 1 : 8 / 1/8

[each ratio reversed (–1)]

first correct …5, second correct …1

(*l*) A laboratory technician diluted 25 cm^3 of a 0.014 M solution to 35 cm^3 by adding deionised water. What was the new concentration of the solution in moles per litre? **5, 1**

$\frac{M_1 \times V_1}{1000} = \frac{M_2 \times V_2}{1000}$ / $M_1V_1 = M_2V_2$ / $\frac{0.014 \times 25}{1000}$ = 0.00035 (moles) …5

$\frac{0.00035 \times 1000}{35}$ = 0.01 (M) / $0.014 \times 25 = M_2 \times 35 \Rightarrow \frac{0.014 \times 25}{35}$ = 0.01 (M) …1

(*m*) Distinguish between an endothermic and an exothermic reaction. **2×3**

endothermic: heat or energy absorbed or taken in / products have more energy than reactants …3

exothermic: heat or energy released or given out / products have less energy than reactants …3

(*n*) Define heat of formation. **2×3**

heat change or heat involved when one mole (of a substance) …3

is formed from its elements in their standard states …3

[one mole omitted ….(–1), standard states omitted …(–1)]

(*o*) Figure 11 shows the structure of 2-anisaldehyde.

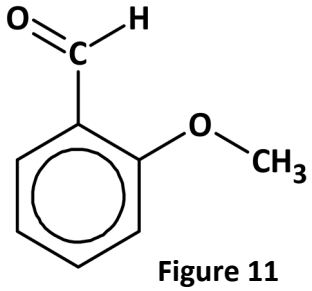


Figure 11

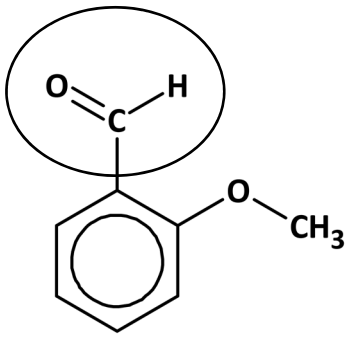


Figure 11 completed

(*i*) Copy the diagram into your answer book and circle the aldehyde functional group.
(*ii*) How many hydrogen atoms has this molecule? **5, 1**

CHO of aldehyde circled
8 / eight

first correct …5, second correct …1

(*p*) Give the systematic IUPAC name for an alcohol has the same molecular formula as diethyl ether ($C_2H_5OC_2H_5$). **6**

butanol / butan-1-ol / 1-butanol / butan-2-ol / 2-butanol / 2-methylpropan-2-ol / 2-methylpropan-1-ol …6

(*q*) Explain why ethanoic acid is very soluble in water. **6**

polarity of functional group / ionises in water / hydrogen bonding / dimerises / …6
[Allow like dissolves like …6]

(*r*) What would you expect to observe, if anything, when a few drops of dilute acidified $KMnO_4$ solution are added to a little propanone in a test tube?
Explain. **2×3**

no change …3
propanone or ketones difficult to oxidise or cannot be oxidised (by $KMnO_4$) …3

QUESTION 8

The arrangement of the elements in the modern Periodic Table is consistent with our understanding of atomic structure and how electrons are arranged in the electron cloud of an atom.

(*a*) (*i*) What is an element? **3**

cannot be broken down into simpler substances chemically / composed only of atoms with same atomic number / substance listed on periodic table …3

(*ii*) How are the elements arranged in the modern periodic table? **5, 1**

according to atomic number

(chemical) properties repeat periodically or at regular intervals / in groups with similar properties

first correct …5, second correct …1

(*b*) (*i*) In terms of arrangement of electrons, what do elements of the same period (row) in the periodic table have in common? **3**

same number of energy levels or shells (occupied by electrons) / outermost electron in same energy level or shell …3

(*ii*) Which of the first 36 elements have their two outermost electrons in an *s* sublevel? **3×2 or 6**

helium or He / beryllium or Be / magnesium or Mg / calcium or Ca /scandium or Sc / Titanium or Ti / vanadium or V / manganese or Mn / iron or Fe / cobalt or Co / nickel or Ni / zinc or Zn any three…3×2

[Cancellation applies]

or

Group 2 or alkali earth elements / d-block elements or transition elements excluding chromium and copper …6

(*iii*) Define an atomic orbital. **2×3**

region or space (around the nucleus of an atom) …3

where the probability of finding an electron is high / where an electron is likely to be found …3

[Area in instead of region or space …(–1)]

(*iv*) Write the *s*, *p*, *d* electron configuration for zinc. **2×3**

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ / [Ar] …3

$4s^2\ 3d^{10}$ / $3d^{10}\ 4s^2$ …3

Why is zinc *not* considered to be a transition element? **3**

doesn't have variable valency / doesn't form coloured compounds / not a good catalyst / has a complete *d* sublevel / doesn't form ion with electron in incomplete *d* sublevel …3

(*v*) Identify the element, of the first 36 elements, that has the largest atomic radius. **3**

potassium / K ..3

Justify your selection. **2×3**

atomic radius decreases across period (as effective nuclear charge increases) …3

increases down group (as number shells or screening or shielding increases) …3

or

[Allow least electronegativity …6]

(*c*) Figure 12 represents the first six energy levels in the electron cloud of a hydrogen atom.

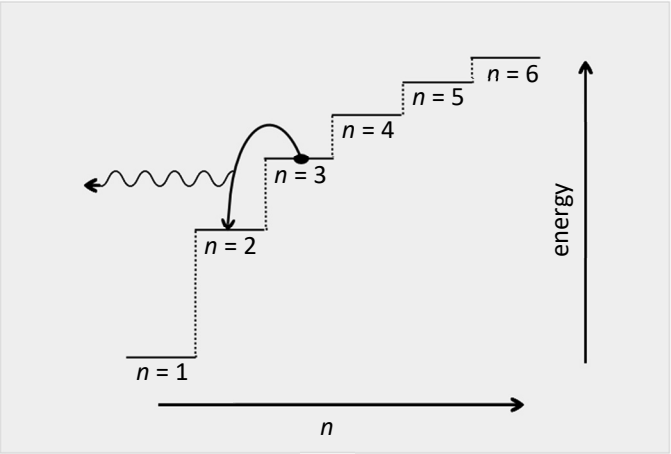


Figure 12

(*i*) Name the scientist who first said that an electron in an atom could occupy only certain energy levels. **1**

Bohr …1

(*ii*) Explain how $E_3 - E_2 = hf$ applies to an electron in a hydrogen atom moving from the third to the second energy level. **2×3, 2**

electron moves from excited state or E_3 or third energy level //
electron arrives at lower energy state or E_2 or second energy level //
photon emitted / electromagnetic radiation emitted / light of definite frequency or wavelength emitted

[symbols explained …8][Do not penalise if ground state given instead of second energy level]

first correct …3, second correct …3, third correct…2

(*d*) The first ionisation energy of sodium is represented by the following equation:

$Na_{(g)} \rightarrow Na^+_{(g)} + e^-$

(*i*) Define the first ionisation energy of a neutral gaseous atom in its ground state. **3×3**

minimum energy (in kJ) required …3
to remove the electron ...3
most loosely bound or outermost from one mole (of atoms) …3
[minimum omitted … (–1), one mole omitted (–1)]

(*ii*) What is the shape of the atomic orbital from which the electron in the equation above is removed? **3**

sphere ...3
[Allow circle stated or drawn …3]

(*iii*) Write a set of quantum numbers that describes this electron before it was removed from the sodium atom. **3**

{3, 0, 0, ½} or {3, 0, 0, –½} …3
[Allow …1 for 3 as 1st quantum number and …1 for ±½ for spin quantum number where …3 not awarded above.]

QUESTION 9

(*a*) Define, according to Brønsted-Lowry theory,

(*i*) an acid,

proton or H^+ donor

(*ii*) a base.

proton or H^+ acceptor

Identify (*iii*) the conjugate acid,

$H_2BO_3^-$

[no charge or incorrect charge …(–1)]

(*iv*) the conjugate base, of HBO_3^{2-}.

BO_3^{3-} **6, 3, 2, 1**

[no charge or incorrect charge …(–1)]

first correct …6, second correct …3, third correct…2, fourth correct…1

Bread soda is a common household chemical. It is a white powder composed of the weak base $NaHCO_3$ and small quantities of other non-basic chemicals.
To determine the percentage of $NaHCO_3$ in a bread soda sample, an aqueous solution of the bread soda was first prepared, and portions of this solution were titrated with a standard solution of sulfuric acid. The sulfuric acid was added to a number of 25.0 cm^3 portions of the $NaHCO_3$ solution in a conical flask to which a few drops of indicator had been added. On average, 16.5 cm^3 of 0.05 M sulfuric acid solution were required for neutralisation. The balanced equation for the titration reaction is:

$$H_2SO_4 + 2NaHCO_3 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$$

(*b*) (*i*) Name the piece of apparatus X shown in Figure 13 which is used to add the sulfuric acid to the conical flask. **6**

burette …6

Describe the correct procedure

(*ii*) for rinsing X before filling it, **2×3**

rinse with deionised or distilled water …3

rinse with sulfuric acid / rinse with (acid) standard solution / rinse with solution it is to deliver or hold …3

[Rinse with water …(–1)] [Rinsing solutions reversed allow …3 max]

(*iii*) for filling X with H_2SO_4 for use in the titration, **2×3**

funnel / use dropper to bring to mark (initially) / fill part below tap /

fill above (zero) mark and open tap to adjust to zero / bottom of meniscus on (zero) mark / no bubbles

any two …2×3

(*iv*) taking a reading from X. **3**

at eye level / read bottom of meniscus / burette vertical / (white) paper behind (to see scale more clearly)

…3

(*c*) A wash-bottle containing deionised water was used to wash down the sides of the conical flask when approaching the end point of the titration.
Explain why this improved the accuracy of the titration. **6**
ensures all acid or base or chemicals react / ensures any splashes or spatters react / avoids addition of excess acid if some is unreacted on walls / ensures an accurate end point volume or measurement / no ions added to interfere with how much acid required to neutralise base …6

(*d*) (*i*) Name a suitable indicator for use in the titration. **3**
methyl orange …3

(*ii*) What colour change would be observed at the end point using this indicator? **2×3**
yellow or orange ...3
pink or red ...3
[allow 3 if colours are reversed]
[Allow correct colour change of phenolphthalein indicator, i.e. pink to colourless]

(*e*) Calculate the concentration of $NaHCO_3$ in the solution titrated
(*i*) in moles per litre, **6, 2, 1**
$\frac{V_1 \times M_1}{n_1} = \frac{V_2 \times M_2}{n_2}$ / (volume × molarity × proticity)$_1$ = (volume × molarity × proticity)$_2$ …6
$\frac{16.5 \times 0.05}{1} = \frac{25.0 \times M_2}{2}$ / 16.5 × 0.05 × 2 = 25.0 × M_2 × 1 …2
(M_2) = 0.066 (M) …1

or
moles of H_2SO_4 used in 16.5 cm^3 = $\frac{16.5 \times 0.05}{1000}$ = 8.25 × 10^{-4} (moles H_2SO_4) …6

$\Rightarrow$1.65× 10^{-3} moles $NaHCO_3$ in 25 cm^3 …2
($\frac{0.00165 \times 1000}{25}$) = 0.066 (moles /L) $NaHCO_3$ …1

(*ii*) in grams per litre. **5, 1**
M_r = 84 …5
84 × 0.066 = 5.544 g per litre …1

The bread soda solution used in the titrations contained 5.67 grams of powder per litre.
(*iii*) What was the percentage purity of the bread soda powder in terms of $NaHCO_3$? **3**
$\frac{5.544 \times 100}{5.67}$ = 97.7 – 98% …3

QUESTION 10

(*a*) (*i*) In terms of electron transfer, what is a reducing agent? **6**

causes another substance to gain electrons / loses electrons …6

[Allow substance oxidised (in redox reaction) …3]

(*ii*) Identify the reducing agent in each of the following reactions:

$2Li + 3N_2 \rightarrow 2LiN_3$

$2I^- + Cl_2 \rightarrow 2Cl^- + I_2$ **6, 3**

lithium / Li

iodide (ion) / I^- first correct …6, second correct…3

(*b*) (*i*) Arrange the elements K, Cu, Zn and Fe in order of their *increasing* ability to act as reducing agents. **6**

Cu, Fe, Zn, K …6

[reversed …3]

(*ii*) Which one of these metals sometimes occurs free in nature? **3**

copper / Cu …3

(*iii*) Identify a metal frequently used as a sacrificial anode to protect iron. **6**

magnesium / zinc / aluminium …6

Give two reasons for its suitability for this use. **2, 1**

more easily oxidised (than iron) / higher up electrochemical series (than iron) / expected to corrode more easily (than iron) / more reactive (than iron) / oxide layers adheres / cheap or cost effective / plentiful / doesn't react with cold water

first correct …2, second correct…1

(*c*) A coin battery like that shown in Figure 14 contains 0.11 g of lithium usually obtained by the electrolysis of LiCl.

Figure 15 shows the electrolysis of molten LiCl using inert electrodes. Some KCl was mixed with the LiCl to lower the melting point of the electrolyte but only the LiCl was electrolysed.

(*i*) Explain the underlined terms. **4×3**

electrodes:

conductor or solid or rod …3

through which electricity enters electrolyte …3

electrolyte:

a substance or ions or salt (which when in solution or molten) // liquid or gel …3

that conducts // that conducts …3

[Examples …2×3]

(*ii*) State Faraday's first law of electrolysis. **2×3**

mass of a substance liberated (at an electrode) is proportional / mass or $m \propto$ …3

to the charge that passes / Q …3

[Allow quantity or amount or number of moles]

(*iii*) Write balanced equations for the reactions that occur at the cathode and at the anode during this electrolysis. **5, 1**

$Li^+ + e^- \rightarrow Li$

$Cl^- \rightarrow (Cl + e^- \rightarrow) \frac{1}{2}Cl_2 + e^- / 2Cl^- \rightarrow (2Cl + 2e^- \rightarrow) Cl_2 + 2e^-$

first correct …5, second correct …1

(*iv*) How long does it take to produce 0.11 g of lithium metal by electrolysis of LiCl using a current of 0.50 A? **3×3 or 9**

($A_r = 7 \Rightarrow \frac{0.11}{7}$ =) 0.0157 (moles Li or moles electrons) …3

$0.0157 \times 96485 = 1510 – 1544$ C / $0.0157 \times 6 \times 10^{23} \times 1.6 \times 10^{-19} = 1510 – 1544$ C ...3

($Q = It \Rightarrow t$ =) 3020 – 3088 seconds / 50.3 – 51.5 minutes …3

[no unit or incorrect unit …. (–1)]

[$Q = It$ ..3 if no other marks awarded]

or

($t = \frac{mass \times F}{A_r \times I} = \frac{0.11 \times 96485}{7 \times 0.5}$ =) 3020 – 3088 seconds / 50.3 – 51.5 minutes …9

[no unit or incorrect unit …. (–1)]

[Allow any order of 0.11 divided by 7 (…3) and multiplied by 96485 (…3) and divided by 0.5 (…3)]

[$t = \frac{mass \times F}{A_r \times I}$ …3 if no other marks awarded]

QUESTION 11

(*a*) (*i*) What is a hydrocarbon? **6**

compound of hydrogen and carbon (only) …6

(*ii*) Name a series of hydrocarbons represented by the general formula C_nH_{2n}. **3**

alkenes / cycloalkanes …3

[Accept ethene, propene, butene …]

(*iii*) What is the minimum value of *n* in this homologous series? **3**

2 (for alkenes) / 3 (for cycloalkanes) …3

(*b*) Some unsaturated hydrocarbons take part in addition reactions.

(*i*) Explain the underlined term. **6**

contains double or triple bond (between carbon atoms) …6

(*ii*) Draw the structure of the product of the addition of bromine to ethene. **3**

CH_2BrCH_2Br …3

[Accept CH_3CH_2Br]

(*iii*) What observation is made as ethene is bubbled through a bromine solution? **6**

red or yellow or orange or red-brown to colourless / decolourises …6

(*iv*) Write a balanced equation for the dehydration reaction used to produce the unsaturated hydrocarbon ethene. **2×3**

$C_2H_5OH \rightarrow$ / $C_2H_5OH + Al_2O_3 \rightarrow$ …3

$C_2H_4 + H_2O$ / $C_2H_4 + Al(OH)_3$ …3

[Not balanced ….(–3)]

(*c*) When methane is mixed with excess chlorine in the presence of ultraviolet light, methane's hydrogen atoms are replaced, one by one, to give a series of four chloroalkanes, the first two of which are chloromethane and dichloromethane.

(*i*) Write a balanced equation for the first reaction in which chloromethane is formed. **2×3**

$CH_4 + Cl_2 \rightarrow$ …3

$CH_3Cl + HCl$ …3

[Not balanced ….(–3)]

(*ii*) Identify the third and fourth chloroalkanes formed in this series of reactions. **6, 5, 1**

trichloromethane / chloroform / $CHCl_3$

tetrachloromethane / carbon tetrachloride / CCl_4

(*iii*) Name the organic reaction type involved in the formation of each of these chloroalkanes.

substitution

first correct …6, second correct …5, third correct…1

(*d*) (*i*) Identify the two compounds that react together to form ethyl ethanoate. **6, 6, 2, 1**

ethanol / C_2H_5OH
ethanoic acid / CH_3COOH

(*ii*) What catalyst is required for this reaction?

sulfuric acid / H_2SO_4 / H^+

(*iii*) What type of reaction is involved?

esterification or ester formation / substitution / condensation / dehydration

first correct …6, second correct …6, third correct…2, fourth correct…1

QUESTION 12

Answer any three parts.

Question 12 (*a*)
Figure 16 shows part of the Guggenheim Museum in Bilbao. The building is clad with thin sheets of an alloy of titanium metal. The metal was extracted industrially from $TiFeO_3$ ore using reactions described by the following balanced equations.
$2TiFeO_3 + 7Cl_2 + 6C \rightarrow 2TiCl_4 + 2FeCl_3 + 6CO$
$TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$

(*i*) How many moles of Ti are there in 6,000 g of the cladding, taking it to contain 92.5% titanium metal by mass? **5, 1**
92.5% of 6,000 = 5,550 (g)
$\frac{5550}{48}$ = 115.6 – 116 (moles titanium)
first correct step …5, second step correct …1

To produce this quantity of titanium using the reactions above, and assuming they go to completion,
(*ii*) what mass of magnesium would be required, **5, 1**
(1 mole Ti $\Rightarrow$ 2 moles Mg $\Rightarrow$ 115.6 moles Ti $\Rightarrow$) 231.25 – 232 (moles Mg) …5
231.25 × 24 = 5,550 – 5,568 (g) …1

(*iii*) what volume of Cl_2 gas measured at s.t.p. would be used up, **5, 1**
(115.6 moles Ti or $TiCl_4$ $\Rightarrow$) 404.6 – 406 (moles Cl_2)
(22.4 × 404.6) = 9063 – 9095 litres Cl_2
first correct step…5, second step correct …1

(*iv*) what mass of $TiFeO_3$ would be required? **3, 1**
M_r ($TiFeO_3$) = 152 …3
(152 × 115.6) = 17,571 – 17,632 (g) …1

Question 12 (*b*)

Define heat of reaction. **2×3**

heat change or heat involved when / heat given out or taken in when …3

when reaction occurs according to a certain balanced equation / for a certain or specific chemical reaction …3

In the fertilizer industry ammonia gas is converted to nitrogen(II) oxide gas in the presence of a catalyst according to the following balanced equation.

$$\mathbf{4NH_{3\,(g)} + 5O_{2\,(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}}$$

Use Hess's law and the information given below to calculate the heat change for the reaction above.

$$\mathbf{\tfrac{1}{2}N_{2\,(g)} + 1\tfrac{1}{2}H_{2\,(g)} \rightarrow NH_{3\,(g)} \quad \Delta H = -45.9\ kJ}$$

$$\mathbf{H_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow H_2O_{(g)} \quad \Delta H = -241.8\ kJ}$$

$$\mathbf{\tfrac{1}{2}N_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow NO_{(g)} \quad \Delta H = 90.3\ kJ}$$ **4×3**

$$4NH_{3\,(g)} \rightarrow 2N_{2\,(g)} + 6H_{2\,(g)} \quad \Delta H = 183.6\ kJ$$ ...3

$$6H_{2\,(g)} + 3O_{2\,(g)} \rightarrow 6H_2O_{(g)} \quad \Delta H = -1450.8\ kJ$$ ...3

$$2N_{2\,(g)} + 2O_{2\,(g)} \rightarrow 4NO_{(g)} \quad \Delta H = 361.2\ kJ$$ ...3

$$4NH_{3\,(g)} + 5O_{2\,(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)} \quad \Delta H = -906\ kJ$$ …3

What is the role of a catalyst in a reaction? **2×2**

speeds up or slows down or alters or controls rate …2

but is not used up …2

[does not take part in reaction unacceptable]

Question 12 (*c*)

Define electronegativity. **2×3**

measure of attraction / measure of force or power of attraction / relative attraction …3

(an atom in a molecule has) for a shared pair of electrons / for electrons in a covalent bond …3

[measure of or power of or relative omitted (–1)]

Distinguish between ionic bonding and covalent bonding. **2×2**

ionic: involves transfer of electrons / involves attraction between oppositely charged ions /

arises where difference in electronegativity values (between the bonding atoms) > or ≥ 1.7 …2

covalent: involves sharing of electrons / involves mutual attraction for shared electrons /

arises where difference in electronegativity values (between the bonding atoms) < or ≤ 1.7 …2

Explain with reference to bonding

(*i*) the high melting point of MgO, **4**

ionic compound / multiple electrostatic attractions or ionic bonds in lattice must be broken (to melt) / ions held together strongly …4

(*ii*) the low boiling point of CH_4, **4**

(non-polar) covalent bonding / little attraction between molecules /

weak intermolecular forces or van der Waals forces or London dispersion forces …4

(*iii*) why diamond is insoluble in water. **4**

covalent bonding / macromolecular or covalent (crystal) /

no attraction between polar water molecules and diamond (atoms) / water is polar covalent …4

[Allow like dissolves like …4]

Question 12 (*d*)

Define pH. **9**

pH = − log[H^+] / pH = − log[H_3O^+] ...9

Calculate the pH of a 0.5 M HCl solution. **2, 1**

pH = –log(0.5) ...2

pH = 0.3 …1

Figure 17 shows the changes in pH as 30 cm^3 of 0.5 M NaOH solution were added to 20 cm^3 of a 0.5 M solution of monobasic acid A.

Use Figure 17 to find

(*i*) the initial pH of the O.5 M solution of A, **4**

2.5 to 3.5 …4

(*ii*) the volume of NaOH added when the pH was 9.0. **4**

20 cm^3 …4

Is acid A strong or weak? **1**

weak …1

Explain your reasoning. **1**

pH (of 0.5 M) > 0.3 / pH at end point above 7 / (pH at) end point basic / steep rise in pH above 7 …1