**Coimisiún na Scrúduithe Stáit**
State Examinations Commission

# Leaving Certificate 2019

# 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, 2019

## PHYSICS AND CHEMISTRY – HIGHER LEVEL

**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

**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*) State Newton's second law of motion.** **2×3**
rate of change of momentum / $m\frac{v-u}{t}$ / change in momentum with time ….3

is proportional to (applied, net) force / $\propto F$ …3
or
acceleration proportional to (applied or net) force / $a \propto F$ …3
and inversely proportional to mass / $a \propto 1/m$ …3
[Allow …6 for $F \propto ma$ or $F = kma$ and…3 for $F = ma$]

**(*b*) Figure 1 represents the kinetic energies of different masses travelling at the same velocity. What is this velocity?** **2×3**
$E_k = ½ mv^2$ / slope = $½ v^2$ / $\frac{y_2 - y_1}{x_2 - x_1} = ½ v^2$ …3
[e.g. $(125 \times 2) \div 10 = v^2 \Rightarrow v$ =] 5 (m s$^{-1}$) or −5 (m s$^{-1}$) / (e.g. $\frac{100}{8} = \frac{v^2}{2} \Rightarrow v$ =] 5 (m s$^{-1}$) or −5 (m s$^{-1}$) …3

**(*c*) An object, starting from rest, travels under constant acceleration of 8 m s$^{-2}$. How long does it take to cover the first 144 m?** **2×3**
$s = ut + ½at^2$ / $v^2 = u^2 + 2as$ and $v = u + at$ …3
$144 = 4t^2 \Rightarrow t$ = 6 (s) / $v^2 = 0^2 + 2 \times 8 \times 144 \Rightarrow$ v = 48 (m s$^{-1}$) and $t = \frac{v-u}{a} = \frac{48}{8}$ = 6 (s) …3

**(*d*) Under what condition is momentum conserved in a system of colliding bodies?** **6**
no external force acts / closed or isolated system …6

**(*e*) Write down two properties of an image formed by a plane mirror.** **2×3**
upright / same size as object / virtual / image distance (from mirror) is same as object distance / laterally inverted any two …2×3

**(*f*) Calculate the focal length of a convex security mirror like that shown in Figure 2 if the image of a person 300 cm from the mirror is formed 50 cm behind the mirror.** **2×3**
$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ / $\frac{1}{f} = \frac{1}{300} + \frac{1}{-50} = \frac{-5}{300}$ …3
[image taken as real (–1)]
–60 (cm) / 60 (cm) …3
[300/7 or 42.9 (cm) …5]

**(*g*) Name the phenomenon where small visible particles suspended in a gas or liquid are observed to be in constant, random motion.** **2×3**
Brownian motion or Brownian movement …3

**What does this phenomenon indicate about the behaviour of the *molecules* of the liquid or gas?**
in constant or rapid or random or straight-line or zig-zag motion /
in continuous agitation / frequently colliding with each other or with visible particles /
indicates the way molecules move any one…3

**(*h*) State Boyle's law.** **2×3**

volume varies inversely with pressure or $V \propto 1/P$ or pressure varies inversely with volume or
$P \propto 1/V$ or $PV$ = constant or $P_1V_1 = P_2V_2$ …3
for a fixed mass of gas at constant temperature …3
[*Either* fixed mass of gas *or* constant temperature omitted (–1)]

**(*i*) What is meant by a thermometric property?** **2×3**

changes (measurably) as temperature changes …3

**On what thermometric property is a liquid-in-glass thermometer based?**

height or volume (of liquid) / expansion (liquid) …3

**(*j*) A transformer for a toy electric railway operates from the 230 V a.c. mains supply and has a 12.0 V a.c. output. The secondary coil has 960 turns.**
**Calculate the number of turns in the primary coil.** **2×3**

$\frac{V_p}{V_s} = \frac{N_p}{N_s}$ / $\frac{230}{12} = \frac{N_p}{960}$ …3

$\Rightarrow$ 18400 …3

**(*k*) Figure 3 shows that a 'three-way' bulb used to produce different brightness levels of light has two filaments, $R_1$ and $R_2$. $R_1$ = 480 Ω and $R_2$ = 960 Ω.**
**Calculate the total resistance of this arrangement of $R_1$ and $R_2$ when both switches are closed.** **2×3**

resistors in parallel / $\frac{1}{R} = \frac{1}{480} + \frac{1}{960}$ …3

$\Rightarrow R$ = 320 (Ω) …3

**(*l*) Give one application of a capacitor in an electrical circuit.** **6**

to separate charge / to store (separated) charge / to store energy (by charge separation) / to release stored energy or charge / block d.c. / filter a.c. from d.c. / smooth output (from an electronic device) /
to tune radio or tv stations / etc …6
[touch screen, photographic flash, mobile phone, defibrillator, fluorescent bulbs etc …3]

**(*m*) Why are high voltages used to transmit electricity over long distances?** **6 or 2×3**

keep current low / reduce heat or power loss (due to resistance) / …6
the bigger the current the more heat produced or lost or wasted in the cables
[Allow reduce costs, more economic, etc ….3]
or
$P = RI^2$ ($\Rightarrow$ low current keeps power loss due resistance in cables low) …3
$P = VI$ ($\Rightarrow$ low current requires high voltage to deliver same power) …3

**(*n*) When a radioisotope emits an alpha particle the new nucleus produced is polonium–218. Identify the radioisotope.** **2×3**

Rn / radon …3
222 …3
[Allow ..3 for Pb–214 or lead–214.]

**(*o*) Define the half-life of a radioactive isotope.** **6**

time taken …3
for half of (radioactive) sample to decay / for activity to fall to half / for half the nuclei to decay …3
[allow 3 marks for $T_{\frac{1}{2}} = \frac{ln2}{\lambda}$ and …3 for λ = decay constant]

**Question 2**

**(*a*) (*i*) What is meant by velocity?** **2×3**

rate of change of / change over time in // rate of change of // speed / …3

displacement // distance (from a point) in a given direction // in a given direction …3

or

$\frac{s}{t} / \frac{ds}{dt}$ …3

*s* is displacement or distance (from a point) in a given direction …3

**(*ii*) What quantity is defined as the rate of change of velocity?** **3**

acceleration …3

**(*iii*) What is the S.I. unit of measurement of the quantity in (*ii*)?** **3**

meter per second per second / metre per second squared / m/s/s / m $s^{-2}$ / $m/s^2$ …3

**(*b*) (*i*) Write an equation to show the relationship between *G*, the gravitational constant and *g*, the acceleration due to gravity at a particular location.** **6**

$g = \frac{GM}{r^2}$ …6

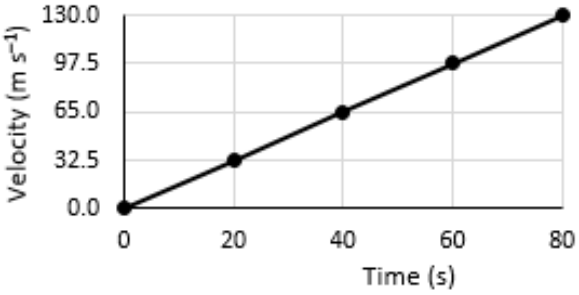
**(*ii*) Why do the values of *g* at the surfaces of the Earth and the Moon differ?** **6**

mass of Moon differs from that of Earth / different masses / Earth heavier / Moon lighter /

radius of Moon differs from that of Earth / different radii / Moon smaller / Earth bigger

any one…6

**(*c*) Figure 4 shows how the velocity of an object changed with time when dropped onto the surface of the Moon.**




**(*i*) Use the graph to estimate a value for $g_m$, the acceleration due to gravity at the surface of the Moon.** **2×3**

($g$ =) $v \div t$ / ($g$ =) $\frac{y_2 - y_1}{x_2 - x_1}$ / $g$ = slope / $v = u + at$ …3

(e.g. 130 ÷ 80 or 97.5 ÷ 60, etc =) 1.6(25) m $s^{-2}$ …3

[no unit or incorrect unit (–1)]

**(*ii*) How far did the object fall in the first 40 s?** **2×3**

$s = ut + ½at^2$ // $v^2 = u^2 + 2as$ // $s = ½(u + v) \times t$ …3

$s = 0t + ½ \times 1.625 \times 40^2 = 1300$ m // $65^2 = 0^2 + 2 \times 1.625 \times s \Rightarrow$ s = 1300m // $s = ½ \times (0 + 65) \times 40 = 1300$ m …3

[no unit or incorrect unit (–1)]

**(*d*) (*i*) Draw a labelled diagram of an arrangement of apparatus you used to measure $g_e$, the acceleration due to gravity at the Earth's surface.** **3×3**

timer / datalogger …3

pendulum string and bob // free-fall apparatus // 1 light gate / 2 light gates …3

pendulum support // trapdoor to activate timer at end of free-fall // double interrupt cards / one card or picket fence …3

[no labels (–1)]

**(*ii*) What two quantities did you measure during the experiment?** **2×3**

time of oscillation(s) // time for free-fall // time(s) for cards or picket fence to go through light gate(s) …3

length of pendulum / length of string and radius of bob // height of free fall // velocity of falling object …3

[length of string (–1)]

**(*iii*) State two precautions taken to ensure an accurate result.** **4, 2**

string as long as possible // height of free-fall big // separation between cards or light gates big

small or heavy bob // small or heavy falling object // heavy card or picket fence

measure time for several oscillations and average // measure time for several free-falls and average or take smallest // measure velocity several times for same drop and average

clear point of suspension for string, e.g split cork // paper between object and magnet // shield card(s) or picket fence from draughts

measure from point of suspension to middle of bob // measure from bottom ball to trapdoor // drop card(s) or picket fence from point high above light gate(s)

get *g* from graph of results

angle of displacement of pendulum small or <5°

first correct …4, second correct…2

[Marks can be awarded for information given clearly in diagram]

**(*iv*) Write the equation you used to calculate $g_e$.** **6**

$T = 2\pi\sqrt{\frac{l}{g}}$ / $T^2 = \frac{4\pi^2 l}{g}$ // $s = ut + ½gt^2$ / $s = ½gt^2$ / $s = ½gt^2$ / $g = \frac{2s}{t^2}$ // $g = \frac{v_2 - v_1}{t}$ …6

**(*v*) If measurements using the apparatus in (*d*) (*i*) could also be taken on the Moon, give a reason why the value of $g_m$ obtained would be more accurate than the value calculated for $g_e$.** **3**

time(s) (for oscillation or free-fall or through light gates) longer //

no air resistance //

less percentage error in time //

etc any one …3

[Allow less percentage error …2]

## Question 3

**(*a*) (*i*) What is meant by the term *ideal gas*?** **6**

particles or molecules consist of point masses /
particles or molecules neither attract nor repel /
particles or molecules exert no forces on each other /
particles or molecules have only perfectly elastic collisions /
obeys the gas laws at all temperatures and pressures or at all conditions /
obeys Boyle's law at all temperatures and pressures or at all conditions …6

**(*ii*) Under what conditions does a real gas most resemble the ideal gas?** **6, 3**

low pressure(s) /
high temperature(s)

first correct…6, second correct…3

**(*iii*) Why does a real gas most resemble the ideal gas under these conditions?** **3**

molecules or atoms or particles size less significant / particles far apart / volume of particles negligible / intermolecular forces less significant
[Allow density low or collisions more elastic or collision time small]

any one …3

**Figure 5 shows how the volume of a fixed mass of gas varies with temperature at different pressures $P_1$, $P_2$ and $P_3$.**

**(*b*) (*i*) What is the exact value of X in °C?** **3**

–273.15 …3

[–273 allow …2]

**(*ii*) What is the significance of this temperature?** **6**

absolute zero / (lower) fixed point on Kelvin or absolute scale / (temperature at which ideal) gas has zero or no volume / only achievable for ideal gas / is achievable only theoretically for real gases /
real gases liquefy before (being cooled to) this temperature …6

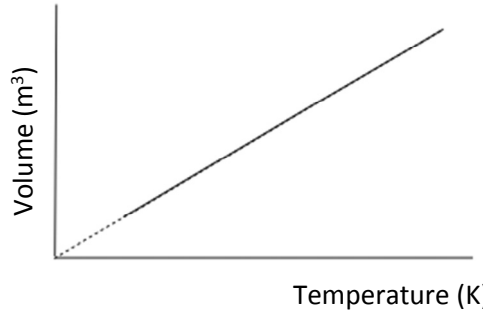
**(*c*) Which of $P_1$, $P_2$ or $P_3$ is the highest pressure?** **6**

$P_3$ …6

**Justify your answer.** **3**

pressure inversely proportional to volume (at given temperature) / Boyle's law /
for greatest volume the pressure must be smallest /
the higher the pressure the smaller the volume …3

**(*d*) (*i*) Sketch the graph you would expect to obtain if the volume of the gas was plotted against absolute temperature at one of these pressures.** **2×3**




axes labelled volume or $m^3$ and temperature or kelvin or K …3
straight line through origin / straight line that if extended would go through origin …3

**(*ii*) Name and state the law illustrated by your graph.** **3, 2×3**

Charles (law) …3

volume of a fixed mass of gas at constant pressure …3
is proportional to its temperature on the Kelvin or absolute scale / increases or decreases by 1/273 for every degree Celsius or kelvin rise or fall or change in temperature …3
[Fixed mass omitted (–1); constant pressure omitted (–1)]
or

$\frac{V_1}{T_1} = \frac{V_2}{T_2} / \frac{V}{T}$ is constant ...3
for a fixed mass of gas at constant pressure and using Kelvin or absolute scale of temperature ...3
[Fixed mass omitted (–1); constant pressure omitted (–1)]

**(*e*) An elastic balloon containing helium had a volume of 0.060 m$^3$ at sea level where the pressure was 99 kPa and the temperature was 22 °C. The balloon was released and rose through the atmosphere until the pressure was 50 kPa and the temperature was – 31 °C. Assuming no helium leaked out and the balloon did not burst, calculate**

**(*i*) the number of moles of helium in the balloon,** **3×3**

(22 + 273.15 =) 295(.15) ….3

$PV = nRT$ / 99 × 10$^3$ × (0.06) = $n$ × 8.31 × 295(.15) …3

[Temperature not in kelvin …. (–3)]

$n$ = 2.4(2) (moles) …3

**(*ii*) the final volume of the balloon.** **2×3**

50 × 10$^3$ × $V$ = 2.4 × 8.31 × 242(.15) / $\frac{0.06 \times 99 \times 10^3}{295(.15)} = \frac{50 \times 10^3 V}{242(.15)}$ …3

0.097 (m$^3$) [0.1 to 0.097 m$^3$] …3

[Slip error for pressure not in Pa and/or volume not in m$^3$ but once only in (*i*) and (*ii*).]

**Question 4**

**(*a*) Define**

**(*i*) the refractive index,** **2×3**

ratio sine of angle of incidence to // sin*i* ÷ // ratio velocity or speed of light in air or a vacuum to // $c_1$ ÷ …3

sine angle of refraction // sin*r* // velocity or speed of light in medium // $c_2$ …3

[reflection instead of refraction …(–3)][sines omitted (–3)]

**(*ii*) 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

**(*b*) Figure 6 shows rays of light from source S striking a liquid-air boundary.**

**(*i*) Calculate the refractive index of the liquid.** **2×3**

$\frac{sini}{sinr}$ / $\frac{sin53}{\sin 35}$ / $\frac{0.80}{0.57}$ // $\frac{sini}{sinr}$ / $\frac{sin35}{\sin 53}$ / $\frac{0.57}{0.80}$ / 0.7125 …3

$n$ = 1.39 – 1.42 // 1/$n$ = 0.7125 $\Rightarrow$ $n$ = 1.39 – 1.42 …3

[Treat as slip error use of radians instead of degrees.]

**(*ii*) Explain which of the angles, W, X, Y or Z is the critical angle.** **2×3**

Y …3

angle of refraction is 90° / ray emerges along water surface …3

[Allow max …3 for W identified as critical angle]

**(*iii*) Copy the diagram and complete it to show the paths of rays R and Q after striking the boundary.** **4×3**

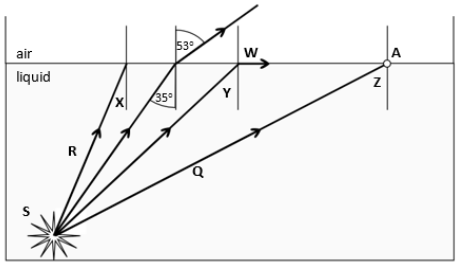



**Figure 6**

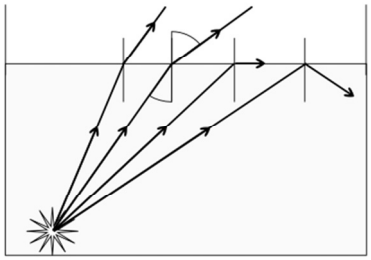


**Figure 6 completed**

R emerges into air …3

R refracted away from normal …3

Q reflected at boundary …3

at approximately correct angle …3

**(*iv*) Name the phenomenon that occurs at the point marked A.** **2×3**

total internal …3

reflection …3

**(*c*) The refractive index of the same liquid was also determined from the measurements of the angles of incidence *i* and the corresponding angles of refraction *r* for a light ray entering a transparent, thin-walled container of the liquid, as shown in Figure 7.**

**These measurements are given in the table.**

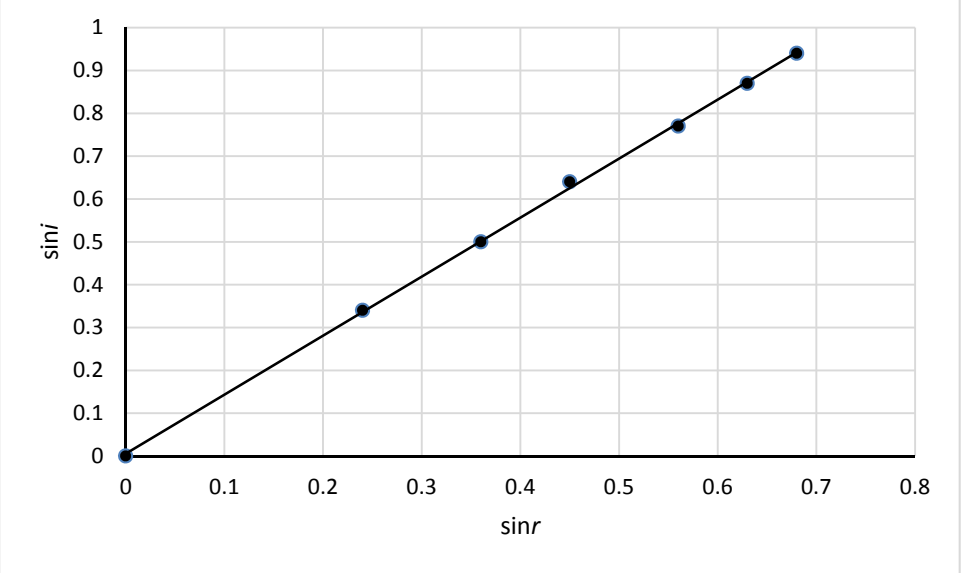
| ***i* (°)** | **0** | **20** | **30** | **40** | **50** | **60** | **70** |
|---|---|---|---|---|---|---|---|
| **sin*i*** | **0** | **0.34** | **0.50** | **0.64** | **0.77** | **0.87** | **0.94** |
| ***r* (°)** | **0** | **14** | **21** | **27** | **34** | **39** | **43** |
| **sin*r*** | **0** | 0.24 | 0.36 | 0.45 | 0.56 | 0.63 | 0.68 |

**(*i*) Copy and complete the last row of the table with sin*r* values correct to two decimal places. 6×1**

| **sin*r*** | **0** | 0.24 | 0.36 | 0.45 | 0.56 | 0.63 | 0.68 |
|---|---|---|---|---|---|---|---|

[rounding to other than two decimal places (–3)]
[each incorrect rounding (–1)]
[sines of radians correctly rounded …3]

**(*ii*) Plot a graph of sin*i* *versus* sin*r* (*x*-axis). 4×3**




axes labelled sin*i* and sin*r* (*x*-axis) …3
axes drawn with appropriate scales …3
five points correctly plotted …3
straight line through these points and origin …3
[Max mark (9) if not on graph paper]
[Max 9 for graph using sines of radians from (*i*) above]

**(*iii*) What is the relationship between sin*i* and sin*r* shown in your graph? 3**
(directly) proportional …3
[mark consequentially if graph is not a straight line through origin]

**(*iv*) How can the refractive index of the liquid be determined from the graph? 3**
slope / $\frac{sini}{sinr}$ …3

**Question 5**

**(*a*) State Ohm's law.** **2×3**

current (in a conductor) is proportional // $I \propto$ // voltage or potential difference is proportional // $V \propto$ …3
to the potential difference or voltage (across it) at constant temperature // *V* at constant temperature //
to current (in a conductor) at constant temperature // *I* at constant temperature …3
[Allow …6 for $V = IR$ at constant temperature]
[at constant temperature omitted (–1)]

**(*b*) The circuit shown in Figure 8 was used to investigate whether the wire filament F obeys Ohm's law.**

**(i) Name the meters X and Y.** **6, 3**

X: ammeter /
Y: voltmeter

first correct…6, second correct…3

**(*ii*) How was this circuit used to determine whether the wire filament obeys Ohm's law?** **6**

change voltage (across F) /
adjust variable resistor (to change *V* or Y or voltmeter reading) …6

**(*iii*) Explain which of the graphs, A, B or C, of current *I versus* voltage *V* shown in Figure 9, would confirm that the wire filament does obey Ohm's law.** **6, 3**

C …6
straight line through origin …3

**(*c*) Calculate**

**(*i*) the current flowing in a 100 W bulb when connected to a 230 V supply,** **2×3**

$P = VI$ / $I = \frac{P}{V}$ …3
($I = \frac{100}{230}$ =) 0.435 A …3
[no unit or incorrect unit …(−1)]

**(*ii*) the resistance of the bulb when this current flows.** **2×3**

$V = IR$ / $R = \frac{V}{I}$ …3
($R = \frac{230}{0.435}$ =) 529 Ω …3
[no unit or incorrect unit …(−1)]

**(*d*) Figure 10 shows the internal structure of a simple dynamo, a direct current (d.c.) generator.**

**(*i*) Name A and B.** **2×6**

A: coil/armature …6
B: brush(es) …6

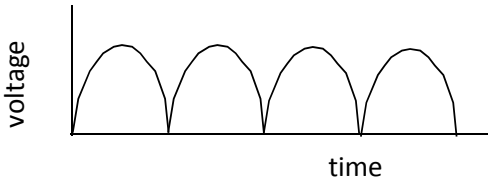
**(*ii*) State the principle of operation of a dynamo.** **3**

an emf or current is induced / electromagnetic induction /
$E = N\frac{d\emptyset}{dt}$ / $E = -N\frac{d\emptyset}{dt}$ / $E = \frac{d\emptyset}{dt}$ / $E = -\frac{d\emptyset}{dt}$ / $E \propto N\frac{d\emptyset}{dt}$ / $E \propto -N\frac{d\emptyset}{dt}$ …3

**(*iii*) What is the main energy conversion that takes place when a dynamo operates?** **2×3**

mechanical energy / kinetic energy …3
to electrical energy …3
[Allow …3 if reversed.]

**(*iv*) Sketch a graph to show how the output voltage (e.m.f) of a dynamo varies with time.** **3**




…3

[Axes need not be labelled]

**Question 6**
**Answer any two parts.**

**Question 6(*a*)**
**Define**
**(*i*) work** **2×3 or 6**
done when point of application of force moves or is displaced // $F \times$ …3
in (same) direction as force / $s$ …3
or
($W =$) $Fs$ …6

**(*ii*) power.** **3**
rate of doing work / rate of using energy / $P = \frac{W}{t} = \frac{E}{t}$ …3

**Which of the following are vector quantities?** **2×3**
**displacement mass energy force power**
displacement …3
force …3
[Cancellation applies if more than two responses given.]

**As an object falls towards the surface of the Earth, what is the relationship between its potential energy and its kinetic energy?** **3**
total potential and kinetic energy unchanged / potential energy converted into kinetic energy /
$E_p + E_k$ = constant / $\Delta E_p + \Delta E_k = 0$ / $mgh$ converted into $\frac{1}{2} mv^2$ …3
[Allow …3 for $mgh = \frac{1}{2} mv^2$ or $E_p = E_k$ in this order taken to mean potential energy is converted to kinetic.]

**An athlete lifted a mass vertically through 60 cm in 0.2 s using a weights machine in a gym.**
**The athlete's average power output was 588 W.**
**Calculate**
**(*iii*) the work done on the mass,** **2×3**
$P = \frac{W}{t} = \frac{E}{t}$ / $W = P \times t$ …3
($W =$) $588 \times 0.2 = 117.6$ J …3
[no unit or incorrect unit …(−1)]

**(*iv*) the average force applied to the mass,** **2×3**
$W = F \times s$ / $F = \frac{W}{s}$ …3
($F =$) $117.6 \div 0.6 = 196$ N …3
[no unit or incorrect unit …(−1)][Answer incorrect multiple of 196 N …(−1)]

**(*v*) the mass lifted.** **3**
($F = mg \Rightarrow m = 196 \div 9.8 =$) 20 kg …3
[no unit or incorrect unit …(−1)]

**Question 6(*b*)**

**What is the S.I. unit of measurement of electrical charge?** **6**

coloumb ...6

[Allow …3 for C]

**Describe, and explain what happens when each of the following is brought near the cap of a *positively*-charged electroscope like that shown in Figure 11:**

**(*i*) a positively-charged plastic rod,** **5, 2**

leaves diverge more / leaves repel more …5

charge on rod attracts electrons up from leaves /
charge on rod attracts electrons to cap …2

**(*ii*) a negatively-charged plastic rod,** **5, 2**

leaves (partially) collapse / leaves converge / leaves come closer together …5

charge on rod repels electrons from cap down to leaves /
electrons attracted to leaves …2

**(*iii*) an uncharged plastic rod.** **1**

leaves (partially) collapse or leaves converge or leaves come closer together because
electrons on rod move towards cap and repel electrons in cap down to leaves …1

**Describe how an electroscope can be used to distinguish between an insulating rod and a conducting rod.** **9, 3**

no change when cap of charged electroscope (is touched) with an insulator and
leaves collapse or converge or a change is observed when cap of charged electroscope (is touched) with a conductor

or

(connect) rod under test between cap of uncharged electroscope and cap of charged electroscope;
no change (in uncharged electroscope) if rod is insulating;
leaves of uncharged electroscope diverge or change or leaves of charged electroscope converge or change if rod is a conductor

**What happens when a person touches the cap of a positively-charged electroscope?**

leaves collapse / charge flows from earth / electroscope discharged / earthing

first correct…9, second correct …3

**Question 6(*c*)**
**Define**
**(*i*) wavelength,** **3**
distance from crest to crest of a wave / distance between two successive crests or troughs / distance between corresponding points on two successive waves …3

**(*ii*) frequency, of a light wave.** **2×3**
number of waves or oscillations (passing fixed point) …3
per second …3

**Calculate the wavelength of an ultraviolet wave whose photons have an energy of $2.0 \times 10^{-18}$ J.** **4×3**
$E = hf$ / $2.0 \times 10^{-18} = 6.626 \times 10^{-34} \times f$ …3
($f$ =) $3.0 \times 10^{15}$ (Hz) …3
$c = f\lambda$ / $3.0 \times 10^{8} = 3.0 \times 10^{15}\ \lambda$ …3
($\lambda$ =) 100 nm / $1.0 \times 10^{-7}$ m …3
[no unit or incorrect unit (−1)]

**Study Figure 12 and**
**(*iii*) name the wave phenomenon illustrated in A,** **3**
diffraction …3

**(*iv*) copy part B and complete it to show the wavefront having passed through a wider slit than it does in A,** **2×3**

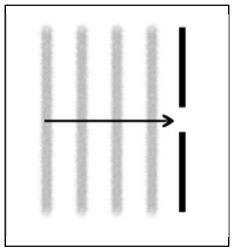


**Figure 12 B, incomplete**

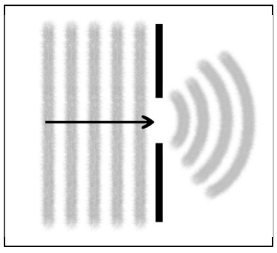


**Figure 12 B, completed**

spreading of wave behind obstacle shown …3
less spreading with longer wavelength through same gap …3

**(*v*) name another phenomenon that occurs when the waves pass simultaneously through two slits as shown in C.** **3**
interference …3
[Allow …3 max for both answers to (*iii*) and (*v*) incorrect but reversed]

**Question 6 (*d*)**

**Identify X, *y* and *z* in the following nuclear reaction:**

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{140}_{54}\mathrm{Xe} + {}^{y}_{z}\mathrm{X} + 2{}^{1}_{0}n + \text{energy}$$ **3×3**

$X$: Sr …3

$y$: 94 …3

$z$: 38 …3

**Identify the type of nuclear reaction involved.** **3**

fission …3

**Explain what is meant by mass-energy conservation.** **6**

mass is a form of energy / energy can be considered equivalent to mass / mass can be converted into energy / energy can be converted into mass / $E = mc^2$ …6

**Consider the following nuclear reaction:**

$$^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}n + \text{energy}$$

**(*i*) Take the mass of a neutron as 1.008664 u and data from page 83 of the *Formulae and Tables* booklet to calculate the mass loss (in u) in this reaction.** **3×3**

($^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H}$ = 2.014 102 + 3.016 049 =) 5.030151 (u) …3

($^{4}_{2}\mathrm{He} + {}^{1}_{0}n$ = 4.002 603 + 1.008664) = 5.011267 (u) …3

(5.030151 − 5.011267 =) 0.018884 (u) …3

**(*ii*) Use data from page 47 of the *Formulae and Tables* booklet to calculate the energy (in J) released in this reaction.**

($m$) = 0.018884 × 1.660 5402 × $10^{-27}$ = 3.135 5764114 × $10^{-29}$ (kg) …3

($E = mc^2$) = 3. 135 764114 × $10^{-29}$ × (2.997 924 58 × $10^{8}$)$^2$ = 2.818284(236) × $10^{-12}$ (J) …3

[No not penalise where candidate expresses final answer in J per mole]

[–3 for inappropriate rounding either in (*i*) or (*ii*), i.e. all decimal places from pages 47 and 83;
–1 for each case of incorrect rounding]

**Question 7**
**Any eleven parts** **11×6**

**(*a*) Identify the *ion* that has 16 protons and 18 electrons.** **6**
$S^{2-}$ …6
[Allow …3 for sulfur with no charge or incorrect charge] …3

**(*b*) What are isotopes?** **2×3**
(atoms with) same atomic number (and) / (atoms of the) same element with / (atoms with) same number protons …3
different mass number / different number of neutrons …3

**(*c*) Write an equation for relationship between the frequency of a line in the hydrogen emission spectrum and two of the main energy levels in a hydrogen atom.** **2×3**
$hf = / f \propto$ …3
$E_2 - E_1 / E_b - E_a$ …3
[Allow any two different subscripts to indicate two energy levels; take (numerical or alphabetical) order to imply emission.]

**(*d*) What name is given to the amount of a compound that contains its relative molecular mass in grams?** **6**
mole …6

**(*e*) Calculate the molarity of a sodium carbonate solution containing 13.25 g $Na_2CO_3$ in 250 $cm^3$.** **2×3**
($M_r$ =) (2 × 23) + 12 + (3 × 16) = 106 …3
($\frac{13.25 \times 4}{106}$ =) $\frac{1}{2}$ (M) / 0.5 (M) …3

**(*f*) $H_2S$ has a permanent dipole moment; $CO_2$ has no permanent dipole moment. What is the shape of (*i*) a $H_2S$ molecule, (*ii*) a $CO_2$ molecule?** **4, 2**
(*i*) V / v—shape(d) / bent
(*ii*) linear
[Diagrams indicating shape acceptable]
first correct…4, second correct…2

**(*g*) Find by calculation the chemical formula of the chloride of phosphorus ($PCl_x$) that contains 77.5% by mass of chlorine.**
**(P = 31, Cl = 35.5)** **2×3**
$\frac{77.5}{35.5}$ / $\frac{22.5}{31}$ / 2.18 / 0.72 …3
($2.18 : 0.72 \Rightarrow$ Cl:P = 3:1 $\Rightarrow$) $PCl_3$ …3

**(*h*) A wooden splint, soaked in water overnight, is dipped in a salt and then held in a Bunsen flame as shown in Figure 13.**
**(*i*) What colour is observed when the salt is NaCl?** **4, 2**
**(*ii*) What metal is present in the salt when a purple flame is observed?**
(*i*) yellow / orange
(*ii*) potassium
first correct…4, second correct…2

**(*i*) What volume is occupied by 51 g of ammonia ($NH_3$) gas at s.t.p.?** **2×3**

$\frac{51}{17}$ = 3 (moles) …3

3 × 22.4 = 67.2 (litres) / 3 × 22400 = 67 200 ($cm^3$) …3

[Accept 67 litres and 67,000 $cm^3$]

**(*j*) Limewater is a saturated solution of calcium hydroxide formed when calcium oxide is added to water.**

**(*i*) Is limewater acidic or basic?**

**(*ii*) Write the chemical formula for calcium hydroxide.** **4, 2**

(*i*) basic

(*ii*) $Ca(OH)_2$

first correct…4, second correct…2

**(*k*) Define heat of combustion.** **2×3**

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

is burned completely / is burned in excess oxygen …3

[one mole omitted …(−1)]

**(*l*) Write a balanced equation for the complete combustion of $C_2H_2$ in oxygen, the reaction that produces an oxyacetylene welding flame.** **2×3**

$C_2H_2 + 2½O_2 \rightarrow 2CO_2 + H_2O$ / $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

formulae …3

balancing …3

**(*m*) Why is excessive burning of hydrocarbon fuels by humans harmful to the environment?** **6**

produces (excess) carbon dioxide / contributes to global warming or (enhanced) greenhouse effect / produces soot / produces acid rain / hydrocarbon fuels contain sulfur that burns to produce $SO_2$ / (large scale) extraction of hydrocarbon fuels can damage physical environment or cause pollution / NO or $NO_2$ or NOx possible (from combustion in petrol engines)

any one …6

**(*n*) (*i*) Name the organic compound whose molecular structure is shown in Figure 14.**

**(*ii*) What is its molecular formula?** **4, 2**

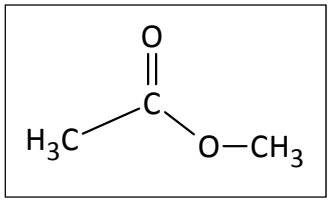
(*i*) methylbenzene / toluene

(*ii*) $C_6H_5CH_3$ / $C_7H_8$

first correct…4, second correct…2

**(*o*) Give the systematic IUPAC name *or* draw the structure of the ester formed from the reaction between methanol and ethanoic acid.** **6**

methyl ethanoate /

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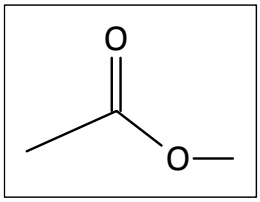


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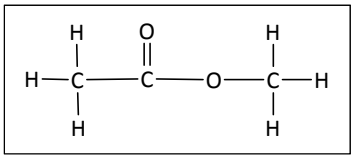



…6

[Hs need not be shown explicitly.]

**Question 8**

**(*a*) Define**

**(*i*) atomic number,** **3**

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

**(*ii*) mass number.** **3**

number of protons and neutrons (in an atom of an element) / number of nucleons (in an atom of an element) …3

**(*b*) State and explain the trend in atomic radii down Group 1 in the periodic table.** **6, 3**

increases …6

additional shell(s) added /

(increased nuclear charge overcome by) additional screening effect or more electrons in inner shells …3

**(*c*) What is meant by the *first ionisation energy* of an element?** **3×3**

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

most loosely bound …3

from one mole of neutral gaseous atoms ...3

[minimum, one mole, neutral, gaseous omitted, (–1) for each]

**(*d*) 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

**Write the (*s*, *p*, etc) electron configuration for**

**(*i*) neon,** **3**

$1s^2\ 2s^2\ 2p^6$ / $1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^2$ / [He] $2s^2\ 2p^6$ ...3

**(*ii*) bromine.** **2×3**

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

$4s^2\ 3d^{10}\ 4p^5$ / $4s^2\ 3d^{10}\ 4p_x^2\ 4p_y^2\ 4p_z^1$ ...3

[Allow superscripts instead of subscripts and vice versa; allow numbers not superscripted.]

**How many atomic orbitals are occupied by electrons in a neon atom?** **3**

5 …3

**(*e*) The reactivity of an element is determined by the number and arrangement of electrons around the nucleus of each of its atoms. Figure 15 shows sodium metal reacting violently in water. Explain why**

**(*i*) the alkali metal, sodium, is so reactive,** **6**

only one electron in outer shell /

easily loses outer electron(s) / gets a stable electron configuration by losing outer electron(s) / gets a stable arrangement of electrons by losing outer electron(s) / very electropositive / low (first) ionisation energy / easily oxidised any one …6

[high up electrochemical or activity series ….3]

**(*ii*) the alkali metals become *more* reactive down their group in the periodic table,** **3**

atomic radius increases / get bigger down group / outer electron(s) farther from nucleus / outer electron(s) more loosely bound / (first) ionisation energy or energies decreasing / more screening (of nucleus) / electronegativity decreasing …3

**(*iii*) bromine is *less* reactive than chlorine.** **3**

electronegativity of bromine smaller / bromine has smaller attraction or affinity for electrons /
bromine radius larger / more screening from bromine nucleus / nucleus farther from outer electrons /
less easily reduced / less reactive down the group any one …3

[Accept opposite statements about chlorine.]

**(*iv*) neon is chemically inert,** **3**

full octet of electrons / full outer or valence shell / full outer subshell / set of full subshells /
stable (configuration or arrangement of electrons) / cannot (easily) gain, share or lose electrons …3

**(*f*) (*i*) How is an ionic bond formed between a pair of atoms?** **3**

transfer of electron(s) (from one atom to the other) / one gains electron(s) that the other loses …3

**(*ii*) How is a double covalent bond formed between a pair of atoms?** **4, 2**

sharing …4

two pairs electrons …2

[Accept answers given as clear dot and cross diagrams.]

**Question 9**

**(*a*) (*i*) Define pH.** **6**

pH = − log[$H^+$] ...6

**(*ii*) Calculate the pH of a 0.30 M sodium hydroxide (NaOH) solution.** **2×3**

pOH = –log[$OH^-$] / pOH = –log(0.30) / (pOH =) 0.52 or 0.5 ...3

pH = 14 – pOH = 13.48 – 13.5 …3

**(*b*) (*i*) Distinguish between a strong acid and a weak acid.** **2×3**

strong acid is fully dissociated …3

weak acid is slightly or partly or not fully dissociated …3

or

strong acid is a good proton donor / …3

weak acid is a poor proton donor …3

**(*ii*) What is the conjugate base of an acid represented by HX?** **3**

$X^-$ …3

[charge omitted –1]

**A 0.30 M solution of NaOH was titrated against 20.0 $cm^3$ of a solution of acid HX using the apparatus shown in Figure 16. The balanced equation for the reaction that occurred is:**

$$HX + NaOH \rightarrow NaX + H_2O$$

**A number of pH readings and the corresponding volumes of NaOH solution added to the acid in the beaker are shown in the table.**

**(*c*) (*i*) Name the piece of equipment A used to add the NaOH solution to the acid.** **3**

burette …3

**(*ii*) Describe how A was rinsed before use.** **2×3**

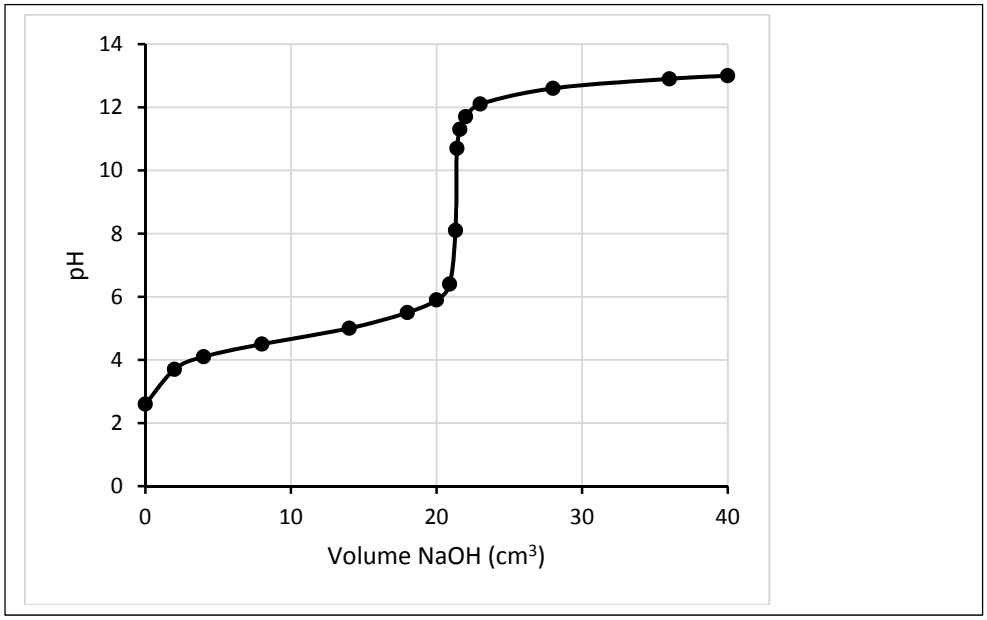
rinse with deionised or distilled water …3

rinse with sodium hydroxide or NaOH / rinse with solution it is to deliver or hold …3

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

**(*d*) Plot a graph of pH (*y*-axis) against the volume of NaOH added.** **4×3**

axes labelled pH (*y*-axis) and volume or NaOH or $cm^3$ …3
axes drawn with appropriate scales …3
7 points shaded in table on right correctly plotted /
overall curve of correct shape …3
smooth curve through points plotted …3
[Max 9 marks if graph not on graph paper]




| Volume **NaOH** ($cm^3$) | pH |
|---|---|
| 0 | 2.6 |
| 2.0 | 3.7 |
| 4.0 | 4.1 |
| 8.0 | 4.5 |
| 14.0 | 5.0 |
| 18.0 | 5.5 |
| 20.0 | 5.9 |
| 20.9 | 6.4 |
| 21.3 | 8.1 |
| 21.4 | 10.7 |
| 21.6 | 11.3 |
| 22.0 | 11.7 |
| 23.0 | 12.1 |
| 28.0 | 12.6 |
| 36.0 | 12.9 |
| 40.0 | 13.0 |

**(*e*) The end-point of the titration corresponds to the sharp rise in pH on the graph.**

**(*i*) Read from your graph the volume of NaOH added at the end point.** **3**

21.3 to 21.5 ($cm^3$) / correct reading from candidate graph …3

**(*ii*) Use this reading and the information given above to calculate the concentration of the acid HX in moles per litre.** **2×3**

$\frac{V_1 \times M_1}{n_1} = \frac{V_2 \times M_2}{n_2}$ / $\frac{21.4 \times 0.30}{1} = \frac{20.0 \times M_2}{1}$ /

(volume × molarity × proticity)$_1$ = (volume × molarity × proticity)$_2$ …3
($M_1$) = 0.321 (M) …3

or

moles of NaOH used in 21.4 $cm^3$ = $\frac{21.4 \times 0.30}{1000}$ = 0.00642 (moles) …3

0.00642 moles of HX $\Rightarrow \frac{0.00642 \times 1000}{20}$ = 0.32 (moles /L) …3

**(*f*) (*i*) Use the pH at the end point to deduce whether HX is a strong or a weak acid.** **3**

weak …3

**Justify your answer.** **3**

above 7 / about 8.7 …3

**(*ii*) Suggest a suitable acid-base indicator to detect the end point of this titration by a colour change.** **3**

phenolphthalein …3

**(*iii*) State the colour change observed at the end point if a few drops of this indicator had been added into the beaker at the start.** **2×3**

colourless ...3

purple or pink or violet ...3

[allow 3 if colours are reversed]

[If (*i*) 'strong', allow methyl orange and its colour change (red to yellow, etc) consequentially. If (*ii*) methyl orange, allow its colour change (red to yellow, etc) consequentially.]

**Question 10**

**(*a*) Iron(III) oxide and aluminium react together rapidly and exothermically in the *thermite* reaction according to the following balanced equation.**

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$$

**The molten iron produced can be used to weld sections of railway track together.**

**(*i*) Define oxidation.** **6**

loss of electrons / gain of oxygen / loss of hydrogen / increase in oxidation number …6

**(*ii*) Which substance is oxidised in the thermite reaction?** **3**

aluminium …3

**(*iii*) Identify the species that loses electrons in the reaction.** **3**

aluminium …3

**(*iv*) Identify the oxidising agent in the reaction.** **3**

**$Fe_2O_3$** …3

**(*b*) (*i*) List Cu, Pb, Al, Fe, K and Au in order of decreasing ease of oxidation.** **6**

K, Al, Fe, Pb, Cu, Au …6

[K first, Au last and Al before Fe …3][reversed …3]

**(*ii*) Which one of these metals has the most heat-stable oxide?** **2×3**

potassium / K …3

[Allow potassium oxide or $K_2O$]

**Justify your answer.**

(ions) most difficult to reduce / potassium highest up the electrochemical or activity series / potassium most reactive, etc …3

**(*iii*) Explain whether copper(II) sulfate crystals should be stored in an aluminium container.** **2×3**

no …3

aluminium displaces copper (from its salts) / aluminium sulfate or $Al_2(SO_4)_3$ formed / aluminium oxidised or corroded / copper ions reduced / copper metal formed / $3CuSO_4 + 2Al \rightarrow Al_2(SO_4)_3 + 3Cu$ …3

['Reaction occurs' alone insufficient.]

**(*iv*) What is *corrosion* of a metal?** **2×3**

oxidation or reaction (of the metal surface) / undesirable process or reaction (of metal) …3

when exposed to air or water or damp air or the environment or (other) chemicals / which converts it to one of its oxides or (other) compounds …3

**(*v*) How *and* why do the resistances to corrosion of iron and of aluminium differ?** **2×3**

aluminium more resistant (to corrosion) / iron corrodes or rusts more easily …3

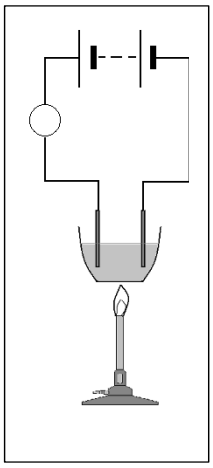
surface oxide protects aluminium / oxide of iron flakes away (exposing more iron) …3

**(*c*) (*i*) Describe with the aid of a labelled diagram how you could demonstrate the electrolysis of molten lead bromide ($PbBr_2$) (m.p. 373 °C) using inert electrodes.** **2×3**

$PbBr_2$ labelled and heated in suitable container …3

battery, circuit and electrodes inserted in $PbBr_2$ …3

[reference to molten electrolyte or ions sufficient if Bunsen burner not shown]



**(*ii*) Why must the $PbBr_2$ be molten?** **3**

ions must be free to move / to conduct electricity …3

**A current of 1.5 A flowed for 12 minutes through a sample of molten $PbBr_2$.**

**(*iii*) What quantity of charge flowed?** **2×3**

$Q = It$ / (Q =) $1.5 \times 12 \times 60$ ...3

(*Q* =) 1080 (C) …3

**(*ii*) What mass of lead was formed?** **2×3**

(1080 ÷ 96485.3383 =) 0.0112 (moles electrons) // (1080 ÷ $1.6 \times 10^{-19}$ =) $6.75 \times 10^{21}$ electrons …3

(207 × (0.0112 ÷ 2) = 207 × 0.0056) = 1.2 (g) // (207 × (($6.75 \times 10^{21} \div 6.022 \times 10^{23}$) ÷ 2)) = 1.2 (g) …3

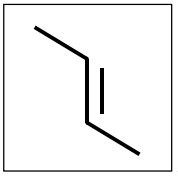
**Question 11**
**Consider the hydrocarbons X = $C_4H_{10}$, Y = but-2-ene and Z = $C_6H_6$.**

**(*a*) (*i*) What is a hydrocarbon?** **2×3**
compound of hydrogen and carbon …3
only …3

**What is an *unsaturated* hydrocarbon?** **3**
contains double or triple bond (between carbon atoms) / could add more hydrogen …3

**(i*i*) Give the IUPAC names for X and Z.** **2×3**
(X =) butane …3
(Z =) benzene …3

**Draw a structure for Y.** **3**
(Y =) …3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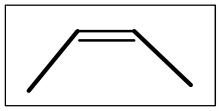
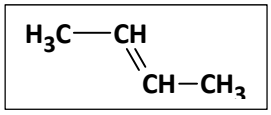

**/**
**$CH_3CHCHCH_3$** **/**



**Why should Z not be used in a school laboratory?** **3**
carcinogen / toxic / poisonous / very harmful …3

**(*b*) A few drops dilute, acidified $KMnO_4$ are shaken in a test-tube containing (*i*) X, (*ii*) Y. State and explain what is observed in each case.** **4×3**
(X) no (colour) change (of reagent) / (pink) colour remains …3
alkane present / X or $C_4H_{10}$ is saturated …3

(Y) colour change (of reagent) / (pink reagent) decolourises …3
alkene present / Y or $C_4H_8$ is unsaturated / addition or oxidation reaction occurs …3

**(*c*) Name the main organic product of the reaction between**
**(*i*) $Br_2$ and but-2-ene,** **5**
2,3-dibromobutane …5
[dibromobutane …4]

**(*ii*) $Br_2$ and $C_6H_6$.** **5**
bromobenzene …5
[Allow dibromobenzene, etc)

**Classify each of these reactions as an addition or a substitution reaction.** **2×3**
(*i*): addition …3
(*ii*): substitution …3

**Which of these reactions occurs only in the presence a catalyst?** **1**
(reaction with) Z or $C_6H_6$ or benzene / second (reaction / (*ii*) …1

**Identify the catalyst involved.** **1**
iron bromide / $FeBr_3$ / iron / Fe / $Fe^{3+}$ …1

**(*d*) What is a functional group?** **3**

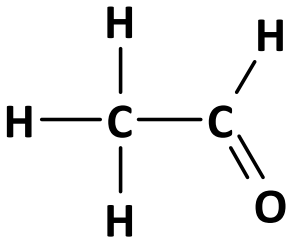
an atom or a group of atoms or a type of bond that gives a(n) (organic) compound characteristic chemical properties …3

**What is a homologous series?** **2×3**

series of compounds with the same functional group /
series of compounds with the same general formula /
series of compounds with same chemical properties /
series of compounds with gradation in physical properties /
series of compounds with similar method of formation /
successive compounds differ by $CH_2$ any two ….2×3

**Draw the structure of the second member of the aldehyde homologous series showing all of its bonds.** **2×3**

ethanal drawn …3
all bonds shown …3




[Hs need not be shown explicitly.][incorrect aldehyde …3]

**Question 12**
**Answer any three parts.**

**Question 12 (*a*)**
**Ozone ($O_3$) and oxygen ($O_2$) are allotropes.**
**(*i*) Define the underlined term.** **6**
different (physical) forms of same element. …6

**$O_3$ at ground level is one of the main causes of the photochemical smog shown in Figure 17. Ozone detector strips are pieces of paper containing chemicals that react with $O_3$ to form $I_2$ according to the balanced equation:**

$$O_{3\,(g)} + 2KI_{(aq)} + H_2O_{(l)} \rightarrow O_{2\,(g)} + 2KOH_{(aq)} + I_{2\,(aq)}$$

**Indicators in the paper darken in the presence of $I_2$ and the colour intensity of the paper after 20 minutes is related to the $O_3$ concentration in the air.**
**Calculate**

**(*ii*) the number of moles of $O_3$ absorbed by a test strip if $6.35 \times 10^{-4}$ g $I_2$ was formed,** **2×3**
$M_r = 254$ …3
$\frac{6.35\times10^{-4}}{254} = 2.5 \times 10^{-6}$ (moles) …3

**(*iii*) the number of *atoms* of oxygen in this quantity of $O_3$,** **8**
$(2.5 \times 10^{-6} \times 3 \times 6 \times 10^{23}) = 4.5 \times 10^{18}$ (atoms O used) //
$(2.5 \times 10^{-6} \times 6.0 \times 10^{23} \times 3) = 4.5 \times 10^{18}$ (atoms O used) …8
[Ans $1.5 \times 10^{18}$ …6]

**(*iv*) the number of moles of KI in the 1.0 $cm^3$ of the 0.025 M solution of KI absorbed by the paper during manufacture of each test strip.** **2**
$\frac{1\times0.025}{1000} = 2.5 \times 10^{-5}$ (moles) …2

**Question 12 (*b*)**

**Nickel is a <u>transition element</u>; its metallic crystalline structure is shown in Figure 18.**

**Explain the underlined term.** **<u>2</u>**

(has) one (cat)ion with an incomplete *d*-subshell / incomplete d-subshell and shows variable valency / in d-block and shows variable valency …2

[Accept (has) incomplete *d*-subshell, comes from d-block of periodic table …(–1)]

[Variable valency on its own not acceptable.]

**Give two characteristic properties of transition metal compounds.** **<u>2×4</u>**

variable valency (of the transition element) / good catalysts / coloured (compounds) any two …2×4

**What is a crystal?** **<u>2×2</u>**

solid with an ordered or regular or repeating or geometric pattern …2

of particles or atoms or ions or molecules …2

**Describe the bonding in a metallic crystal like nickel.** **<u>2×2</u>**

positive ions …2

sharing (some or valence) electrons / with (some) delocalised electrons / in a sea of electrons …2

[Diagram acceptable]

**Would you expect nickel to be a good electrical conductor?** **<u>2</u>**

yes …2

**Explain.** **<u>2</u>**

(valence) electrons free to move

[metallic insufficient] …2

**Question 12 (*c*)**

**State Hess's law.** **3×2**

heat change for a reaction // algebraic sum of heat changes of the stages equal to …3

independent of path followed / depends only on initial and final states // heat change for reaction taking place in one step …3

**Hydrogen cyanide (HCN), a poisonous substance important in the polymer industry, is synthesised from methane and ammonia by the following reaction.**

$$\mathbf{CH_{4\,(g)} + NH_{3\,(g)} \rightarrow HCN_{\,(g)} + 3H_{2\,(g)}}$$

**Calculate the heat change for this reaction given the following information:**

$$\mathbf{N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH_{3\,(g)} \qquad \Delta H = -91.8\ kJ}$$

$$\mathbf{C_{(s)} + 2H_{2\,(g)} \rightarrow CH_{4\,(g)} \qquad \Delta H = -74.9\ kJ}$$

$$\mathbf{2C_{(s)} + H_{2\,(g)} + N_{2\,(g)} \rightarrow 2HCN_{(g)} \qquad \Delta H = 270.3\ kJ}$$

**4×3**

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

$$CH_{4\,(g)} \rightarrow C_{(s)} + 2H_{2\,(g)} \qquad \Delta H = 74.9\ kJ \quad ...3$$

$$C_{(s)} + \tfrac{1}{2}H_{2\,(g)} + \tfrac{1}{2}N_{2\,(g)} \rightarrow HCN_{(g)} \qquad \Delta H = 135.15\ kJ \quad ...3$$

$$CH_{4\,(g)} + NH_{3\,(g)} \rightarrow HCN_{(g)} + 3H_{2\,(g)} \qquad \Delta H = 255.95\ kJ \quad ...3$$

[Accept 255.95 to 256 kJ.]

**Is the reaction of methane with ammonia exothermic or endothermic?** **2**

endothermic …2

**Give one use for the $H_2$ gas, the co-product of this HCN synthesis.** **2**

fuel / (weather) balloons / making ammonia / making margarine / hardening vegetable oils / etc …2

**Question 12 (*d*)**

**Define electronegativity.** **2×3**

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

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

[force of attraction or power of attraction (–1)]

**Explain how electronegativity values can be used to predict**

**(*i*) whether an ionic compound is formed when two elements react,** **3**

significant difference in electronegativity values / difference in electronegativity values > or ≥ 1.7 …3

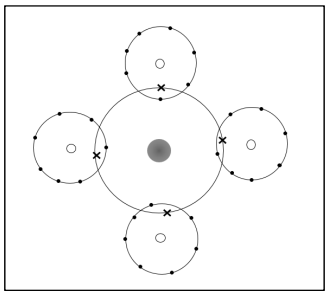
**(*ii*) the polarity of a single covalent bond formed between two atoms.** **3**

the smaller the difference in electronegativity values the less polar the bond /

difference in electronegativity values < or ≤ about 0.4 for non-polar or pure covalent bond /

difference in electronegativity values > about 0.4 for polar covalent bonds …3

**Draw a dot and cross diagram to show the bonding in a molecule of tetrachloromethane ($CCl_4$).** **4, 2**



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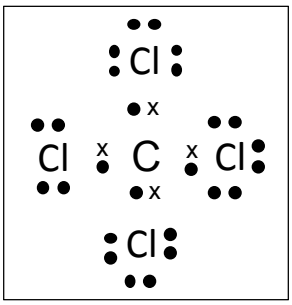


4 bond pairs in valence shell carbon …4

other valence electrons correct …2

**Why is the $CCl_4$ molecule non-polar while the C-Cl bond it contains are slightly polar?** **2**

centre of positive charge coincides with centre of negative charge / no net dipole moment /

degree (type) of symmetry …2

**Explain whether you would expect $CCl_4$ to be water soluble.** **2×1**

no …1

non-polar / no (net) dipole moment / no attraction for polar water molecules / no dipole-dipole

interactions / only van der Waals forces / …1

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