Coimisiún na Scrúduithe Stáit

State Examinations Commission

Leaving Certificate 2021

Marking Scheme

Physics and Chemistry

Higher Level

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

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

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

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

Future Marking Schemes

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

General Guidelines

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

1. In many instances only key words are given, 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 **<u>11×6</u>**

(*a*) Identify the scalar quantities in the following:

mass velocity force energy time **<u>3×2</u>**

mass …2

energy …2

time …2

(*b*) Figure 1 is a work-time graph.

Find the average power developed over the 5 s. **<u>3</u>**

($P = \frac{W}{t} = \frac{1000}{5}$ =) 200 W …3

Is power constant in this case? **<u>3</u>**

no …3

[Allow $P = \frac{W}{t}$ for …(3), if no other marks awarded.]

(*c*) State the *principle of conservation of momentum*. **<u>2×3</u>**

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)]

(*d*) The blink of an astronaut's eye lasts 0.11 seconds.

How far does light travel in space in that time? **<u>2×3</u>**

$d = vt$ / $s = vt$ / $d = ct$ / $s = ct$ / distance = speed × time …3

($d = s$ =) $2.998 \times 10^8 \times 0.11 = 3.2978 \times 10^7$ (m) [$3.2977 \times 10^7 - 3.3 \times 10^7$] …3

(*e*) What is meant by the triple point of water? **<u>6</u>**

ice, (liquid) water, steam coexist / 273.16 K or 0.01 °C …6

[unit omitted here …(–1)]

(*f*) Sketch the graph obtained when the volume of a fixed mass of gas at constant pressure is plotted against its temperature in ^{0}C. **<u>2×3</u>**

increasing linear graph of volume versus temperature …3

intercept on temperature axis is left of zero / graph goes through positive volume-axis …3

(*g*) State the thermometric property used in each of the following: **<u>4, 2</u>**

(*i*) a liquid-in-glass thermometer,

height or length or volume (liquid)

(*ii*) a constant-volume gas thermometer.

pressure

first correct …4, second correct …2

(*h*) Give two characteristics of a good thermometer. **<u>4, 2</u>**

sensitive / large change on scale for small rise in temperature //
small heat capacity //
accurate //
large or useful temperature range //
easy to use or read / convenient //
small //
responds quickly //
robust, etc

first correct …4, second correct …2

(*i*) State Snell's law. **<u>2×3</u>**

ratio of sine of angle of incidence // $\frac{sini}{sinr}$ …3
to sine of angle of refraction is constant // = *n* or *k* or constant …3

or

sine of angle of incidence proportional to or varies directly with // sin*i* ∝ …3
sine of angle of refraction // sin*r* …3

[reflection instead of refraction (–3)]
[(–3) for each sine omitted]

(*j*) Identify the phenomenon occurring at (*i*) X, (*ii*) at Y in Figure 2 as a ray of light travelling in air strikes and travels through the prism. **<u>4, 2</u>**

X: refraction
Y: total internal reflection

first correct …4, second correct …2

(*k*) Name a phenomenon which can be explained only by reference to **<u>4, 2</u>**
(*i*) the wave nature of light,
interference / diffraction / polarisation / Doppler effect,
(*ii*) the properties of photons of light.
photoelectric effect / black body radiation / origin of spectra / etc

first correct …4, second correct …2

(*l*) *F* is the force between two identical charges a distance apart. When the separation between their centres is doubled, what is the new force between them in terms of *F*? **<u>6</u>**

F ÷ 4 or *F*/4 …6
[4*F* ….(3)][$F \propto \frac{q_1 q_2}{d^2}$ or $F = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{d^2}$….(3)]

(*m*) The electrical field pattern in Figure 3 is produced when two charges Q_1 and Q_2 are placed close together. What type of charge, positive or negative, is **<u>2×3</u>**
(*i*) Q_1
negative …3
(*ii*) Q_2?
positive …3

(*n*) Calculate the size of the charge, in μC, transferred when a 0.6 μF parallel-plate capacitor is connected to a 6 V power supply. **<u>2×3</u>**

$C = \frac{Q}{V}$ / $Q = CV$ …3
(Q =) 0.6 × 6 = 3.6 (μC) or 4 (μC) …3

(*o*) What is electromagnetic induction? **<u>2×3</u>**

change in the magnetic flux linking or through a coil // *E* = // *E* ∝ ...3

producing or inducing an emf in the coil or results in current (flow) in the coil // $-N\frac{d\emptyset}{dt}$// $-\frac{d\emptyset}{dt}$ or $\frac{d\emptyset}{dt}$ ...3

(*p*) Assuming no power loss during operation of a step-up transformer, how do **<u>2×3</u>**

(*i*) the sizes of the output voltage and input voltage compare,

output voltage bigger / $\frac{V_{in}}{V_{out}} = \frac{N_{in}}{N_{out}}$ / $V_{out} > V_{in}$ ...3

(*ii*) the sizes of the output current and the input currents compare?

output current smaller / $\frac{I_{in}}{I_{out}} = \frac{V_{out}}{V_{in}}$ / $\frac{I_{in}}{I_{out}} = \frac{N_{out}}{N_{in}}$ / $I_{out} > I_{in}$ ...3

(*q*) In terms of sub-atomic particles what, is **<u>4, 2</u>**

(*i*) an alpha-particle,

helium nucleus / two protons and two neutrons / ${}^{4}_{2}\mathrm{He}^{2+}$

[helium atom or ${}^{4}_{2}\mathrm{He}$ ...(–1)]

(*ii*) a beta-particle?

electron or e^- or ${}^{0}_{-1}e$ / positron or e^+ or ${}^{0}_{1}e$

first correct ...4, second correct ...2

(*r*) What is the half-life of a radioactive isotope whose activity decreases to 1/16th of its original value in 32 hours? **<u>2×3</u>**

1 to ½ to ¼ to 1/8 to 1/16 or 4 half-lives ...3

32 ÷ 4 = 8 (hours) ...3

QUESTION 2

(a) (*i*) State Newton's second law of motion. **2×3**

rate of change of momentum is proportional to // $\frac{mv-mu}{t} \propto$ …3

force acting and (takes place) in the same direction or direction of force // *F* and in same direction …3

[in the same direction or direction of force omitted …(–1)]

(*ii*) Derive the relationship *force* = *mass* × *acceleration* from this law. **3×3**

$F \propto \frac{mv-mu}{t}$ / $F \propto m(\frac{v-u}{t})$ …3

($\Rightarrow$) $F \propto ma$ / ($\Rightarrow$) $F = kma$ …3

($\Rightarrow$) $F = ma$ when $k = 1$ / ($\Rightarrow$) $F = ma$ in SI system …3

[$F = ma$ without $k = 1$ or without reference to SI system (–1)]

(*b*) (*i*) Draw a labelled diagram of an arrangement of apparatus used to verify that the acceleration of a fixed mass is proportional to the force applied. **4×3**

trolley on track …3

sloped track or a smooth frictionless horizontal track or air track …3

attached by string over pulley to weights …3

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

(*ii*) How is the mass being accelerated kept constant? **3**

masses or weights transferred between trolley and end of (vertical) string …3

(*iii*) What measurements are recorded? **3×3**

accelerating force / masses used to create force to pull trolley …3

times through two light gates / times to travel initial distance and final distance / velocity …3

time between light gates / distance between light gates …3

(*c*) A small object dropped from a height on a construction site could cause severe injury if it struck a person on the ground. See Figure 4.

The graph in Figure 5 shows how the magnitude of the vertical momentum of an object of mass *m* varied with time over the first few seconds of its fall from a height, starting from rest, when the only force acting on it was gravitational.

(*i*) After the first 3.0 s the object had a vertical speed of 29.4 m s^{-1}.
Use the graph to find *m*. **2×3**

(momentum or *mv* after 3.0 s =) 147 …3

$m = \frac{mv}{v} = \frac{147}{29.4}$ = 5.0 kg or 5 kg …3

[no unit or incorrect unit …. (–1)]

(*ii*) What quantity is determined by the slope of the graph? **3**

force / weight …3

(*iii*) Calculate the slope of the graph. **2×3**

$\frac{147-0}{3-0}$ / $\tan\theta = \frac{147}{3}$ …3

49 …3

(*iv*) How far did the object fall in the first 3.0 s? **3×3**

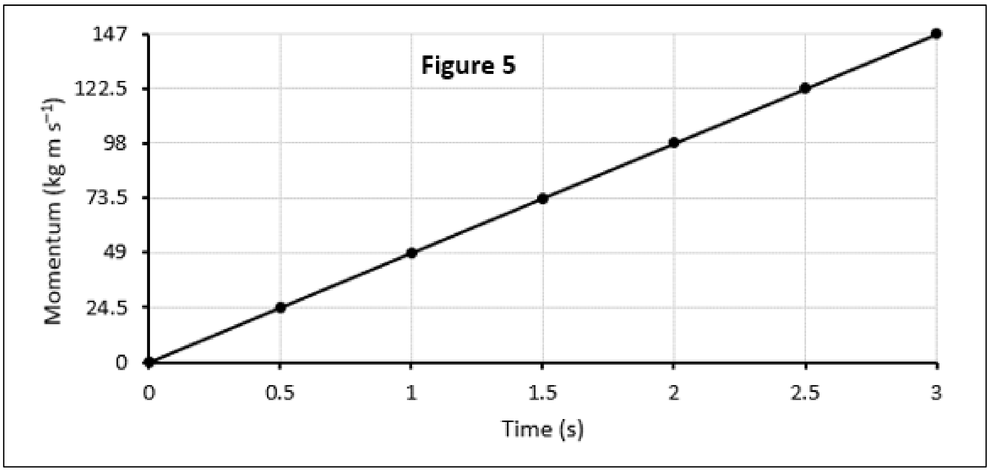
($F = ma \Rightarrow a = 49 \div 5 =$) 9.8 m s^{-2} …3

$s = ut + ½at^2$ / $s = ½at^2$ / $s = ½gt^2$ // $v^2 = u^2 + 2as$ / $v^2 = 2as$ / $v^2 = 2gs$ …3

$\Rightarrow = 0.5 \times 9.8 \times 9.0 = 44.1$ m // $(29.4)^2 = 2 \times 9.8 \times s \Rightarrow s = 44.1$ m or 44 m …3

[no unit or incorrect unit …. (–1)]

(*v*) Explain how the graph is consistent with Newton's second law. **3**



straight line through the origin /
rate of change of momentum is constant when the force applied is constant /
rate of change of momentum is equal to or (directly) proportional to constant (gravitational) force /
constant acceleration of fixed mass (directly) proportional to constant (gravitational) force /
$mv \propto t \Rightarrow ma$ = constant …3
[origin omitted …(–1)]

QUESTION 3

(*a*) (*i*) State the laws of reflection of light. <u>**6, 3**</u>

incident ray, reflected ray and normal in the same plane /
angle of incidence equal to angle of reflection
[refraction instead of reflection (–3) but once only]

first correct…6, second correct …3

(*ii*) Describe an experiment to find the position of the image of an object formed by a plane mirror. <u>**3×3**</u>

mark position of object and back of mirror // mark (diverging) incident rays and back of mirror …3
find position of image (by no parallax) // mark reflected rays …3
using search pin // project (diverging) reflected rays back to (apparent) point of origin …3
[Marks available for points shown or described.]

(*b*) Draw a ray diagram to show image formation in a convex mirror. <u>**2×3**</u>

one ray reflected correctly from convex mirror …3
second ray reflected correctly intersecting first to show image formation correctly …3

(*c*) An object was placed 9 cm in front of a plane mirror, a convex mirror and a concave mirror, in turn. A <u>virtual image</u> was formed in each case.

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

(image) formed by apparent intersection of light rays / (image) cannot be formed on a screen …6

(*ii*) How far was the image formed behind the plane mirror? <u>**3**</u>

9 cm …3
[no unit or incorrect unit …. (–1)]

(*iii*) Find the focal length of the convex mirror if the image distance in the case of the convex mirror was 3 cm less than the image distance in the plane mirror. <u>**2×3**</u>

$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ / $\frac{1}{f}=\frac{1}{u}-\frac{1}{v}$ / $\frac{1}{f}=\frac{1}{9}-\frac{1}{6}$ …3
($\Rightarrow \frac{1}{f}=-\frac{1}{18}$ and f =) (–) 18 cm …3
[Award (3) for 3.6 cm] [no unit or incorrect unit …. (–1)]
[Drawing to scale acceptable.]

(*iv*) Find the image distance in the case of the concave mirror when its focal length was equal in magnitude to the focal length of the convex mirror. <u>**2×3**</u>

($\frac{1}{f}=\frac{1}{u}+\frac{1}{v}\Rightarrow$) $\frac{1}{18}=\frac{1}{9}\pm\frac{1}{v}$ …3
$\frac{1}{v}=-\frac{1}{18}\Rightarrow$ (v =) (–) 18 cm …3
[Award (3) for (–) 6 cm using f = –18 cm]
[no unit or incorrect unit …. (–1)]
[Drawing to scale acceptable.]

(*v*) What was the magnification in each one of the three cases of reflection? **<u>3, 3×2</u>**

m = v/u …3

plane: (magnification or *m* =) 1 / no or zero magnification …2

[*m* = 0 incorrect but apply (–1)]

convex: $(m = \frac{v}{u} = \frac{6}{9}$ =) $\frac{2}{3}$ / 0.667 / two thirds size of object …2

concave: $(m = \frac{v}{u} = \frac{18}{9}$ =) 2 / twice size of object …2

[ignore negative signs]

(*d*) Convex mirrors are frequently used as rear-view mirrors in motor vehicles.
State

(*i*) an advantage, **<u>3</u>**

wide field of view / image upright …3

(*ii*) a disadvantage, of using convex mirrors instead of plane mirrors for this purpose. **<u>3</u>**

makes object appear farther away than it actually is / more difficult to judge actual positions of objects / image diminished / image distorted …3

(*iii*) Give one use for a concave mirror and state why it is suitable for this use. **<u>2×3</u>**

dentist mirror or shaving mirror or make-up mirror // reflector in torch, projector, etc …3

magnified image // projects or reflects parallel beam …3

QUESTION 4

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

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

at all temperatures and pressures ...3

(*ii*) How is the kinetic theory used to explain how a gas exerts pressure? **3**

molecular or particular collisions with walls of container ...3

(*iii*) Under what conditions do real gases behave most like the ideal gas? **2×3**

low pressure ...3

high temperature ...3

(*b*) What is the effect of increasing the pressure of a sample of gas at constant temperature on

(*i*) the average kinetic energy of the molecules of the gas, **3**

none / no effect ...3

(*ii*) the volume of the gas? **3**

decreases ...3

Explain your answer in each case. **2×3**

average kinetic energy: molecular kinetic energy changes (only) with temperature ...3

volume: pressure inversely proportional to volume / volume decreases as pressure increases / pressure squeezes gas into smaller volume / reference to or statement of Boyle's law ...3

(*c*) The graph in Figure 6 shows how the pressure of a fixed mass of gas varies with its volume at three different temperatures.

(*i*) Name and state the law verified in Figure 6. **3×3**

Boyle ...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)]

[These marks can be awarded for work given in part (*ii*)]

(*ii*) Draw a labelled diagram of an apparatus suitable for use in verifying this law. **3×3**

fixed mass of gas with mechanism to vary volume (at constant temperature) ...3

mechanism to vary pressure ...3

gauges or scales or digital recording to read volume and pressure ...3

(*iii*) Describe how the measurements required to draw the graph were obtained. **2×3**

read volume and pressure (and temperature) ...3

find reciprocal of volume ...3

(*iv*) Which is the lowest temperature, T_1, T_2 or T_3? Justify your answer. **2×3**

T_1 ...3

slope or pV proportional to T / slope smallest for T_1 / from $PV = nRT$ /
the lower the pressure the lower the temperature (for a certain volume or $1/V$) / etc ...3

(*d*) Chlorine gas is widely used to purify drinking water supplies. A sample of chlorine gas occupies 8.7 litres at a pressure of 1.19 × 10^5 Pa and a temperature of 24 ^{o}C. Calculate the temperature at which this sample of chlorine gas occupies a volume of 10.2 litres at a pressure of 1.13 × 10^5 Pa. **3×3**

$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ // $pV = nRT$ …3

$\frac{1.19 \times 10^5 \times 8.7}{297} = \frac{1.13 \times 10^5 \times 10.2}{T_2}$ // $n = \frac{pV}{RT} = \frac{1.19 \times 10^5 \times 8.7 \times 10^{-3}}{8.31 \times 297} = 0.419$ moles …3

[Using 24 ^{o}C in calculations is **not** a slip in this step.]

(T_2 =) 330 – 331 K or 57 – 58 ^{o}C // (T_2 =) = $\frac{pV}{nR} = \frac{1.13 \times 10^5 \times 10.2 \times 10^{-3}}{0.419 \times 8.31}$ = 330 – 331 or 57 – 58 ^{o}C …3

[no unit or incorrect unit …. (–1)][Do not penalise for unit if answer is 26.7 ^{o}C.]

QUESTION 5

(*a*) Define electric current. <u>**6**</u>

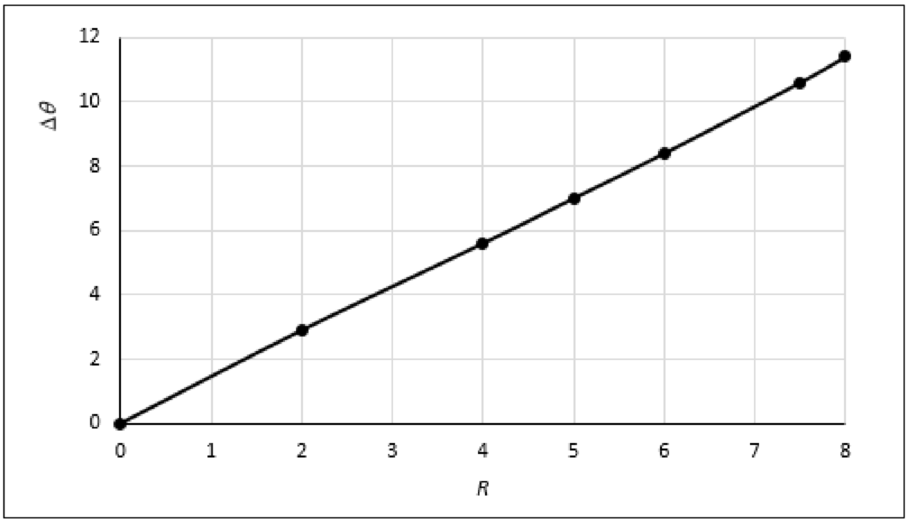
flow or movement of electrons or charged particles or ions or charge ...6

(*b*) In an experiment to investigate the heating effect of an electric current, a student first measured the changes in temperature $\Delta\theta$ when the same current current passed through heating coils of different resistances *R* (immersed in a fixed mass of water in identical containers for the same time).
The following data were recorded.

***R* (Ω)**	**0**	**2.0**	**4.0**	**5.0**	**6.0**	**7.5**	**8.0**
$\Delta\theta$ (°C)	**0**	**2.9**	**5.6**	**7.0**	**8.4**	**10.6**	**11.4**

(*i*) Plot a graph of $\Delta\theta$ *versus R* (*x*-axis). <u>**4×3**</u>

axes labelled *R* or resistance and or $\Delta\theta$ or temperature rise* ...3
axes scaled correctly ...3
six points correctly plotted ...3
straight line through origin ...3



(*ii*) Use the graph to predict the temperature rise when *R* = 3.5 Ω. <u>**3**</u>

4.9 – 5.2 °C ...3
[no unit or incorrect unit …. (–1)]

(*iii*) What relationship between temperature rise and resistance is shown by your graph? <u>**3**</u>

temperature rise* proportional to resistance / $\Delta\theta \propto R$ ...3

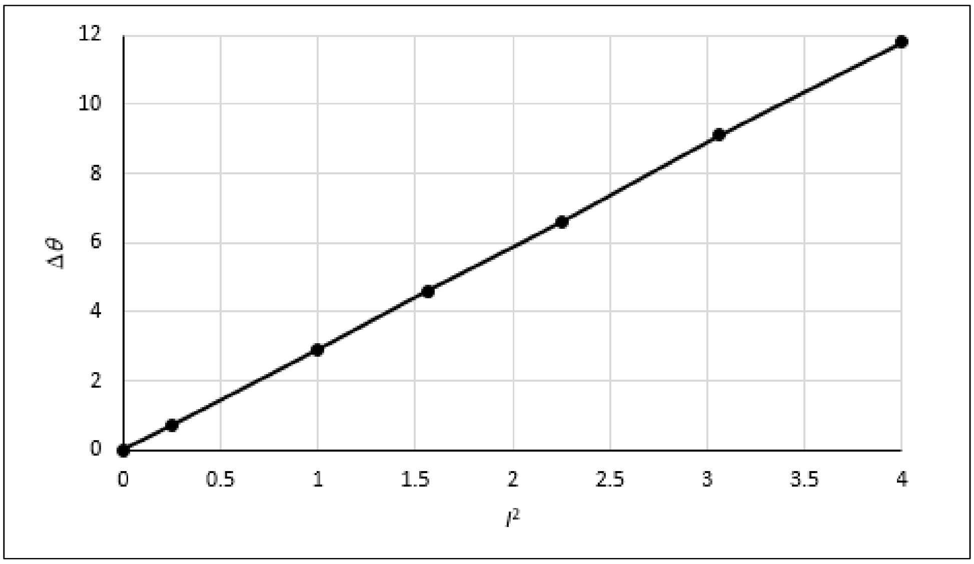
(*c*) **The student then measured the changes in temperature $\Delta\theta$ when different currents *I* were passed through the same heating coil (immersed in a fixed mass of water in identical containers for the same time). The following data were recorded.**

I (A)	**0**	**0.5**	**1**	**1.25**	**1.5**	**1.75**	**2**
$\Delta\theta$ (^oC)	**0**	**0.7**	**2.9**	**4.6**	**6.6**	**9.1**	**11.8**

(*i*) **Plot a graph of $\Delta\theta$ versus I^2 (*x*-axis).** **4×3**

I^2 (A^2)	0	0.25	1	1.56	2.25	3.06	4

I^2 values in table or on graph …3
axes labelled I^2 or current^2 and or $\Delta\theta$ or temperature rise* …3
axes scaled correctly and six points correctly plotted …3
straight line through origin …3



(*ii*) **Use the graph to predict the current associated with a temperature rise of 8.8 ^oC** **2×3**
(I^2 =) 3 to 3.3 …3
($\Rightarrow I$ =) 1.7 or $\sqrt{3}$ – 1.8 A …3
[no unit or incorrect unit …. (–1)]

(*iii*) **What relationship is shown by your graph?** **3**
temperature rise* proportional to square of current / $\Delta\theta \propto I^2$ …3

[*Penalise (–3) for temperature instead of temperature rise but once only for all work on (*b*) and (*c*) together.]

(*d*) **Figure 7 represents a current-carrying wire passing through a square of cardboard.**
Copy the diagram into your answerbook and complete it to show the magnetic field associated with the current *I* in the wire. **<u>2×3</u>**

concentric circular field lines around wire (at least 2) …3
direction anticlockwise (at least one arrow) …3

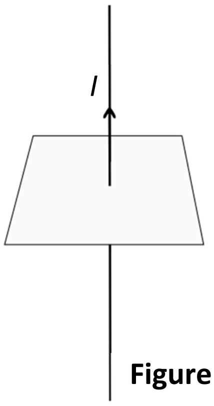


Figure 7

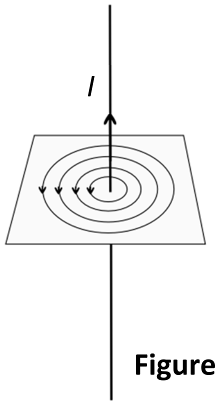


Figure 7 completed

(*e*) **Figure 8 shows a metal wheel which rotates anti-clockwise when the switch is closed.**
(*i*) **What principle is demonstrated by this arrangement?** **<u>2×3</u>**

current carrying wire in magnetic field …3
experiences a force …3
[Allow (6) for motor effect or (Fleming's) left hand rule.]

Suggest how you could make the wheel
(*ii*) **rotate faster,** **<u>3</u>**

increase current / increase strength of magnet / increase height of magnet …3

(*iii*) **rotate clockwise.** **<u>3</u>**

reverse direction of current / reverse direction of magnetic field …3

(*iv*) **Give an example of an appliance based on the principle demonstrated by this arrangement.** **<u>3</u>**

motor / meter / loudspeaker / any named appliance containing motor or meter as its primary function …3

QUESTION 6

Answer any two parts.

Question 6(*a*)

Define the S.I. unit of energy, i.e. the joule. **2×3**

force of 1 newton or 1 N // mass of 1 kg moves at 1 m s^{-2} …3

moves a mass 1 m in the direction of the force // 1 m in the direction of the force …3

[in the direction of the force omitted …(–1)]

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

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

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

Space shuttles were designed to be launched vertically, orbit the Earth in space carrying out various missions, re-enter the Earth's atmosphere, land on runways like gliders.
How much potential energy was required to raise a space shuttle of mass 1.03 × 10^5 kg to a height of 110 m above the launch pad? **2×3**

(E =) mgh / (E =) $1.03 \times 10^5 \times 9.8 \times 110$ …3

(E =) 1.11×10^8 J or 111,034,000 J …3

[no unit or incorrect unit …. (–1)]

After launch, a shuttle docked with the international space station and together they orbited Earth with at a distance of 6.78 × 10^3 km from the center of the Earth.
Find the gravitational force on the shuttle and space station if their combined mass was 5.10 × 10^5 kg and the mass of the Earth is 5.97 × 10^{24} kg. **3×3**

(F =) $G\,\frac{M_1 M_2}{d^2}$ …3

(F =) $6.67 \times 10^{-11}\,\frac{(5.10 \times 10^5)(5.97 \times 10^{24})}{(6.78 \times 10^6)^2}$ …3

(F =) 4.42×10^6 N / 4.42×10^{12} μN …3

[no unit or incorrect unit …. (–1)]

A shuttle and its contents of combined mass 9.04 × 10^4 kg returned to the surface of the Earth after a mission with a horizontal touchdown velocity of 105 m s^{-1}.
How much energy was converted into other forms, e.g heat, sound, etc., to bring the shuttle to rest after touchdown on a horizontal runway? **2×3**

(E =) $\frac{1}{2}mv^2$ / (E =) $\frac{1}{2} \times 9.04 \times 10^4 \times (105)^2$ …3

(E =) 4.9833×10^8 J to 5×10^8 J …3

[no unit or incorrect unit …. (–1)]

Question 6(*b*)

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)]

The circuit in Figure 9 contains four identical 5 Ω bulbs W, X, Y and Z and a 9 V battery. Find

(*i*) the total resistance of this arrangement of bulbs, **3×3**

parallel: $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} / \frac{1}{R} = \frac{1}{5} + \frac{1}{5}$ …3

$\Rightarrow R = 2.5$ (Ω) …3

series: 2.5 + 5 + 5 = 12.5 (Ω) …3

(*ii*) the current flowing in each bulb. **4×3**

same current in W and X / current W = current X / $I_W = I_X$ …3

$V = IR$ / 9 = I × 12.5 ⇒(I =) 9 ÷ 12.5 = 0.72 (A) …3

same current in Y and Z / current Y = current Z / $I_Y = I_z$ …3

($I_Y = I_z$ =) 0.36 A or 0.4 A* …3

[*no unit or incorrect unit …(−1)]

Describe what would be observed

(*iii*) if bulb Y blew, **3**

other bulbs stay lighting / Z brighter or W and X dimmer / 0.6 A in each bulb …3

(*iv*) if bulb X blew. **3**

no light …3

Question 6(*c*)

Figure 10 represents the electromagnetic spectrum. This is a series of different types of radiation, arranged in order of frequency, that have certain common characteristics, including their speed in a vacuum.

(*i*) Identify the type of radiation in each of the regions A and B of the spectrum. **2×3**

A: infrared …3

B: *x*-rays …3

(*ii*) Give an application for each of the radiations in regions A and B. **2×3**

A: heating / night vision equipment or photography / remote controls / security beams / dark-room lighting, etc …3

B: medical diagnostic / detecting contraband in security checks (at airports, etc) / detecting cracks or faults in metals / detecting fraud in art / treating cancer, etc …3

[Accept correct applications of incorrect *electromagnetic* radiations given in (*i*) only.]

(*iii*) How can the radiation from region A be detected? **3**

(blackened) thermometer (bulb) / heating effect …3

(*iv*) Electromagnetic waves are <u>transverse</u> waves that can undergo <u>diffraction</u> and interference. Explain the underlined terms. **4×3**

transverse:

direction of propagation perpendicular // electric field perpendicular …3

to vibration of particles of medium // to (associated) magnetic field …3

diffraction:

spreading out of wave or wavefronts …3

on passing through a gap or slit or passing by an obstacle …3

[Marks can be awarded for information conveyed in clear labelled diagrams.]

(*v*) **Find the wavelength associated with an FM radio wave of frequency 88.2 MHz.** **2×3**

$c = f\lambda \Rightarrow \lambda = \frac{c}{f} = \frac{2.998\times10^8}{88.2\times10^6}$ …3

(λ =) 3.4 m / 3.4 × 10^6 Mm …3

[no unit or incorrect unit …(−1)]

Question 6(*d*)

Consider the nuclear reaction: $^{235}_{92}\mathbf{U} + {}^{1}_{0}\mathbf{n} \rightarrow {}^{144}_{56}\mathbf{Ba} + {}^{89}_{w}\mathbf{Kr} + x{}^{1}_{0}\mathbf{n}$ + energy.

What type of nuclear reaction is involved? **3**

fission …3

What are the values of w and x in the equation above? **2×3**

w: 36 …3

x: 3 (neutrons) …3

How could this reaction result in a chain reaction occurring in a sample of uranium–235? **6**

if at least one neutron released causes more fission or fission of another uranium (nucleus) / more neutrons produced than used up …6

Consider the nuclear reaction: $^{3}_{2}\mathbf{He} + {}^{3}_{2}\mathbf{He} \rightarrow {}^{b}_{a}\mathbf{Y} + 2{}^{1}_{1}\mathbf{H}$ + energy.

What type of nuclear reaction is involved? **3**

fusion …3

Identify the element Y and the values of a and b. **3×3**

Y: helium / He …3

a: 2 …3

b: 4 …3

Why is this type of nuclear reaction only possible under extreme conditions? **2×3**

nuclei must move at high speeds or nuclei have high (kinetic) energy / temperature high / very high energy …3

to overcome (electrostatic) repulsive forces / because (positive) nuclei repel …3

QUESTION 7.

Any eleven parts **11×6**

(*a*) **How many (*i*) neutrons, (*ii*) electrons, does a $^{48}_{22}\mathrm{Ti}^{2+}$ ion have?** **2×3**

26 (neutrons) …3

20 (electrons) …3

(*b*) **Figure 11 represents an electron transition from one energy level (E_3) to another (E_2) in an excited hydrogen atom. What coloured line in the hydrogen emission spectrum is associated with this specific transition?** **6**

red …6

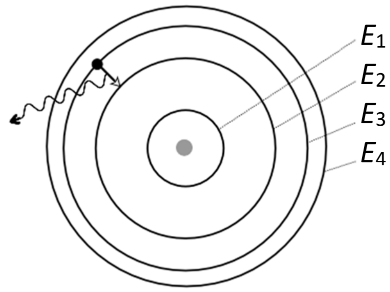


Figure 11

(*c*) (*i*) **What is an anion?** **2×3**

negative ion / negatively charged atom or group of atoms / atom or group of atoms that has gained an electron or electrons …3

(*ii*) **Identify a group in the periodic table of the elements whose atoms are likely to form anions when bonding.**

halogens / Group 17 / Group 7 / chalcogens / Group 16 / Group 6 …3

[If cation defined in (i) allow marks for correct group given in (ii)]

(*d*) **Does a water molecule have an overall dipole moment?** **2×3**

yes …3

Explain your answer.

centres of negative and positive charge do not coincide or do not cancel (in H_2O) /
vector sum of individual dipoles not zero /
distribution or arrangement of polar bonds around oxygen or around central atom has insufficient symmetry /
two bond pairs and two lone pairs /
valence electron pairs or bonds (in H_2O) arranged in v /
valence electron pairs or bonds (in H_2O) not linear …3

(*e*) **How many atoms are there in 3.36 litres of carbon dioxide gas measured at s.t.p.?** **2×3**

$\frac{3.36}{22.4} = 0.15$ (moles) / …3

$0.15 \times 3 \times 6 \times 10^{23} = 2.7 \times 10^{23}$ (atoms) …3

[9×10^{22} (–1)]

(*f*) **Ice and dry-ice are examples of molecular crystals. What are the forces between**

(*i*) **the water molecules in ice,** **4, 2**

hydrogen bonds

[allow dipole dipole interactions]

(*ii*) **the carbon dioxide molecules in dry-ice?**

van der Waals forces / London dispersion forces / temporary dipoles interactions

first correct …4, second correct …2

(*g*) What are allotropes of an element? **6**
different physical forms (of the same element) …6
[physical omitted (–3)] [example only …3]

(*h*) Explain why metallic crystals are good conductors of electricity. **2×3**
electrons …3
free (to move) …3

(*i*) Write a balanced equation for the reaction of iron(III) oxide with carbon monoxide forming iron metal and carbon dioxide. **2×3**
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ formulae…3
balancing …3

(*j*) What is a catalyst in a chemical reaction? **2×3**
speeds up or slows down or alters or controls rate …3
but is not used up …3
[does not take part in reaction unacceptable]

(*k*) State two characteristic properties of transition elements. **4, 2**
metallic / good catalysts / form coloured compounds / variable valency
first correct …4, second correct …2

(*l*) What is meant by an amphoteric oxide? Give an example. **2×3**
acts as either an acid or as a base / both acidic and basic …3
Al_2O_3 / ZnO / H_2O / BeO / PbO / SnO, etc …3

(*m*) Define heat of solution. **2×3**
heat change or heat involved when one mole / heat given out or taken in when one mole …3
dissolves in excess solvent or water …3
[one mole omitted …(–1)][evolved instead of involved …(–1)]

(*n*) Burette stopcocks like that shown in Figure 12 are often made of Teflon, a polymer with formula $(C_2F_4)_n$ where *n* is a large number. Calculate the percentage of fluorine by mass in Teflon. [C = 12; F = 19]
2×3
M_r C_2F_4 = (24 + 76) = 100 // M_r $(C_2F_4)_n$ = (24 + 76)n = 100n …3
$\frac{76}{100} \times 100 = 76\%$ // $\frac{76n}{100n} \times 100 = 76\%$ …3

(*o*) A bromine solution, in a test-tube wrapped in aluminium foil to keep out the light, was decolourised when a gaseous hydrocarbon was bubbled through it.
What conclusion may be drawn about the hydrocarbon? **6**
unsaturated / has a double or triple bond / is an alkene or alkyne …6

(*p*) Which of the following compounds would you expect to have the strongest carbon-carbon bonding: ethane, ethene, ethyne, benzene? **6**
ethyne …6

(*q*) **Show that propanal and propanone are structural isomers, i.e. they have the same molecular formula (C_3H_6O) but different structural formulae.** **<u>4, 2</u>**

CH_3CH_2CHO / C_2H_5CHO

CH_3COCH_3

[Hs need not be shown explicitly]

first correct …4, second correct …2

(*r*) **Identify the aromatic compounds shown in Figure 13.** **<u>4, 2</u>**

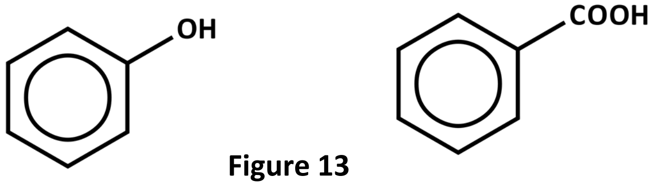


Figure 13

phenol / hydroxybenzene / benzenol

benzoic acid / carboxybenzene / benzene carboxylic acid

first correct …4, second correct …2

QUESTION 8

An electron in an atom is associated with an orbital, a sublevel, and a main energy level.

(*a*) (*i*) 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)]

(*ii*) Write the *s*, *p* electron configuration for aluminium. **2×3**

$1s^2\ 2s^2\ 2p^6$ / $1s^2\ 2s^2\ 2p_x^{\,2}\ 2p_y^{\,2}\ 2p_z^{\,2}$ …3

$3s^2\ 3p^1$ / $3s^2\ 3p_x^{\,1}$ …3

How do the following orbitals in an atom of aluminium differ:

(*iii*) the 2*s* and the 3*s* orbitals, **6**

2*s* smaller or closer to nucleus / 3*s* larger or farther from nucleus /

2*s* lower in energy / 3*s* higher energy / 2s part of second energy level and 3s part of third energy level …6

(*iv*) the 2*s* and the $2p_x$ orbitals, **6**

s has spherical shape, *p* has dumbbell shape /

2*s* lower energy than 2*p* / 2*p* higher energy than 2*s* …6

[allow …3 for 'different shapes' on its own]

(*v*) the $2p_x$ and the $2p_y$ orbitals? **6**

orientation or alignment or arrangement in space different /

arranged along *x*, *y* axes or at right angles …6

[where p_x and p_y drawn to indicate different orientations, do not cancel 'different shape']

(*b*) (*i*) Define first ionisation energy of an element. **3×3**

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]

(*ii*) The *second* ionisation of sodium is represented by the equation:

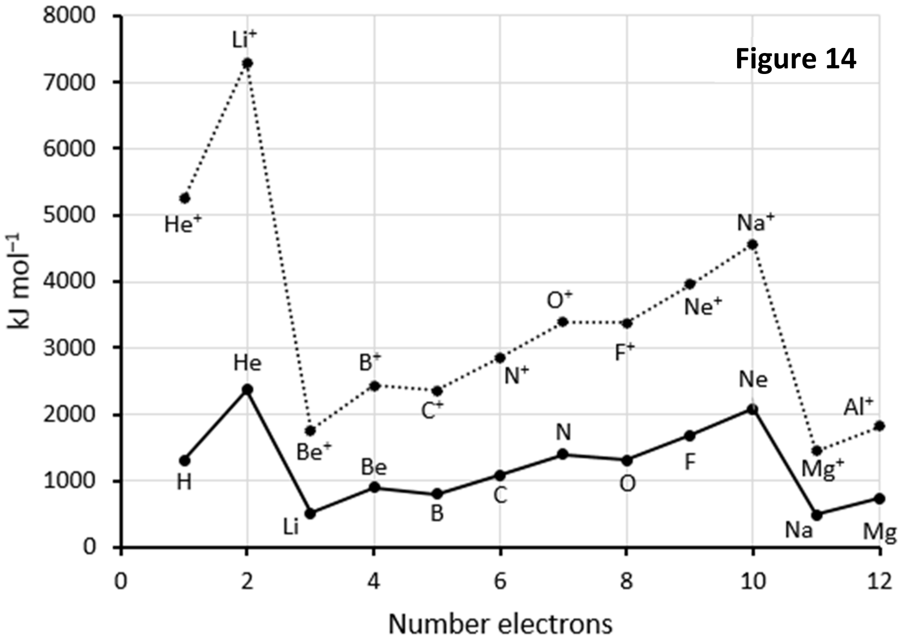
$$Na^+_{(g)} \rightarrow Na^{2+}_{(g)} + e^-$$

Write a similar equation to represent the *first* ionisation of boron (B). **3**

$B_{(g)} \rightarrow B^+_{(g)} + e^-$ …3

[gaseous symbols omitted (–1)]

Figure 14 shows the first ionisation energy values for the elements hydrogen to magnesium and the second ionisation energy values for helium to aluminium.



(*iii*) Account for the high first ionisation energy value of helium compared to the other elements. <u>**6, 3**</u>

(outermost) electron(s) close to nucleus / (outermost) electron(s) in first shell / (outermost) electron(s) not shielded from nucleus / small atomic radius / (outermost) electron(s) in a full shell

first correct …6, second correct…3

(*iv*) Explain the general increase in the first ionisation energies from lithium to neon shown in the graph *and* the peaks that occur at beryllium and nitrogen. <u>**6, 2×3**</u>

(effective) nuclear charge increasing or atomic number increasing or number of protons increasing / atomic radius decreasing …6

*(outermost) electron of beryllium in a full sublevel or full subshell or stable configuration …3

*(outermost) electron of nitrogen in an (exactly) half-full full sublevel or an (exactly) half-full subshell or stable configuration …3

[*Orbital or shell instead of subshell (–3) but apply penalty once only in (*iv*)]

(*v*) Why is the second ionisation energy of lithium so high? <u>**3**</u>

(outermost) electron(s) close to nucleus / (outermost) electron(s) in first shell / (outermost) electron(s) not shielded from nucleus / (outermost) electron(s) in a positive ion / (outermost) electron(s) in a full shell …3

QUESTION 9

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

(*i*) an acid, <u>3</u>

proton donor ...3

[Arrhenius definition unacceptable.]

(*ii*) a acid-base conjugate pair. <u>3</u>

two species that differ by a proton or H^+ ...3

(*iii*) Distinguish between a weak acid and a strong acid. <u>2×3</u>

strong acid is a good proton donor / ...3

weak acid is a poor proton donor ...3

or

strong acid is fully dissociated / large K_a ...3

weak acid is slightly or partly or not fully dissociated / small K_a ...3

(*iv*) Carbonic acid (H_2CO_3) is a weak acid formed when carbon dioxide dissolves in water. What is the conjugate base of carbonic acid? <u>3</u>

HCO_3^- ...3

[no charge or incorrect charge ...(–1)]

(*v*) Define pH. <u>6</u>

$pH = -\log[H^+]$ / $pH = -\log[H_3O^+]$ ...6

(*vi*) Calculate the pH of a 0.08 M sodium hydroxide (NaOH) solution, correct to one decimal place. <u>2×3</u>

$pOH = -\log[OH^-]$ / $pOH = -\log(0.08)$ / (pOH =) 1.1 ...3

pH = 14 – pOH = 12.9 ...3

(*vii*) Fizzy drinks allowed to stand open to the air gradually go 'flat', i.e. they lose dissolved CO_2. Would you expect the pH of a fizzy drink to increase or decrease as it goes flat? <u>3</u>

increase ...3

(*b*) Many fizzy drinks contain citric acid ($C_6H_8O_7$), a weak tribasic acid as a flavouring. To determine the concentration of citric acid in a colourless fizzy drink, that had been allowed go flat, 25.0 cm^3 portions of the drink were titrated with a *standard solution* of 0.08 M sodium hydroxide in the presence of phenolphthalein indicator.

Taking $R(COOH)_3$ to represent the tribasic citric acid, the balanced equation for the neutralisation reaction can be given as: $R(COOH)_3 + 3NaOH \rightarrow R(COONa)_3 + 3H_2O$
A pipette like that shown in Figure 15 was used to measure a 25.0 cm^3 portion of flat fizzy drink into a conical flask for each titration.
How should

(*i*) the pipette, <u>6, 3</u>

rinse with deionised or distilled water ...3

rinse with (flat) drink or citric acid solution / rinse with solution it is to deliver or hold ...3

[Rinse with water ...(–1)] [Rinsing solutions reversed allow ...6 max]

first correct ...6, second correct...3

(*ii*) **the conical flask, have been prepared for use?** **<u>3</u>**
rinse with deionised or distilled water ...3
[second rinsing contradicts]

(*iii*) **What determines the number of 25.0 cm^3 portions of flat fizzy drink that needed to be measured out and titrated?** **..3**
until at least two agree closely or agree to within 0.1 cm^3 ...3
[Allow 'one rough and then two' or 'three' titrations ...3]

(*c*) **The <u>standard solution</u> of sodium hydroxide was added from a burette.**
(*i*) **Explain the underlined term.** **<u>3</u>**
concentration known ...3

(*ii*) **What colour change was observed at the end point in the conical flask using phenolphthalein indicator?** **<u>2×3</u>**
colourless ...3
purple or pink or violet ...3
[allow ...3 if colours are reversed]

(*d*) **On average 13.3 cm^3 of 0.08 M NaOH was required to neutralise 25.0 cm^3 of the citric acid solution according to the balanced equation above.**
Calculate the concentration of citric acid ($C_6H_8O_7$) in the fizzy drink
(*i*) **in moles per litre,** **<u>2×3</u>**
$\frac{V_1 \times M_1}{n_1} = \frac{V_2 \times M_2}{n_2}$ / $\frac{13.3 \times 0.08}{3} = \frac{25.0 \times M_2}{1}$ /
(volume × molarity × proticity)$_1$ = (volume × molarity × proticity)$_2$ ...3
(M_1) = 0.0142 (M) ...3

or
moles of NaOH used in 13.3 cm^3 = $\frac{13.3 \times 0.08}{1000}$ = 0.001064 (moles) ...3

$\Rightarrow \frac{0.001064 \times 1000}{25 \times 3}$ = 0.014 (moles /L) citric acid ...3

(*ii*) **in grams per litre.** **<u>2×3</u>**
M_r = 192 ...3
192 × 0.014 = 2.7 g per litre or 3 g per litre ...3

QUESTION 10

Corrosion of a metal involves oxidation of the metal. Extraction of a metal from its ore involves reduction of a compound of the metal.

(*a*) (*i*) Define the underlined terms. **2×3**

oxidation: loss of electrons …3

reduction: gain of electrons …3

(*ii*) Identify the substance acting as the reducing agent in the following reaction.

$Al_2O_3 + 3H_2 \rightarrow 2Al + 3H_2O$ **6**

H / H_2 / hydrogen …6

(*b*) (*i*) What is the list of elements in order of decreasing ease of oxidation called? **3**

electrochemical series / activity series / reactivity series …3

(*ii*) Arrange the following elements in order of decreasing ease of oxidation:
Al, Pb, Ag, Mg, Na, Fe and hydrogen. **6**

Na, Mg, Al, Fe, Pb, H_2, Ag …6

[Only Pb misplaced (–1)]

[reversed …3]

(*iii*) Figure 16 shows a rusting padlock. Explain why iron is observed to corrode more rapidly than aluminium. **6, 3**

aluminium more easily oxidised / aluminium higher up electrochemical series / aluminium expected to corrode more easily /
oxide of iron or rust flakes off or is more soluble exposing more metal (to corrosion) /
oxide of aluminium protects aluminium (from corrosion)

first correct …6, second correct…3

(*iv*) Describe two ways, that involve chemical reactions, of preventing corrosion. **6, 3**

electroplating is using electrolysis to coat one metal with another /
anodising involves thickening oxide layer (on aluminium) by electrolysis /
sacrificial anode is attaching a more reactive metal to delay corrosion /
galvanising is coating with a more reactive metal to delay corrosion

first correct…6, second correct …3

[any two…2×3 for two examples without description or incorrectly described]

(*c*) Magnesium is extracted by the electrolysis of molten $MgCl_2$ using inert electrodes.

(*i*) Explain the underlined terms. **2×3, 6**

electrolysis:

using electricity …3

to bring about a chemical reaction / to split compound into its elements …3

inert electrodes:

(conduct current but) do not take part in (electrode) reactions …6

[example only …3]

(*ii*) Write balanced equations for the reactions that occur at the cathode and at the anode during this electrolysis. **<u>2×3</u>**

$Mg^{2+} + 2e^{-} \rightarrow Mg$ ...3

$Cl^{-} \rightarrow (Cl + e^{-} \rightarrow)\ \tfrac{1}{2}Cl_2$ / $2Cl^{-} \rightarrow (2Cl + 2e^{-} \rightarrow)\ Cl_2 + 2e^{-}$ ...3

[take order of question unless equations labelled]

(*iii*) When 4.8 kg of magnesium was produced in this way, what charge passed through the electrolyte? **<u>3×3</u>**

$A_r = 24 \Rightarrow \frac{4800}{24} = 200$ (moles Mg) / 0.2 (kilomoles Mg) ...3

$\Rightarrow 2 \times 200 = 400$ (moles electrons) / 0.4 (kilomoles Mg) ...3

$400 \times 96485 = 3.84 \times 10^{7}$ C to 3.9×10^{7} C / $400 \times 6 \times 10^{23} \times 1.6 \times 10^{-19} = 3.84 \times 10^{7}$ C to 3.9×10^{7} C /
$0.4 \times 96485 = 3.84 \times 10^{4}$ kC to 3.9×10^{4} kC / $0.4 \times 6 \times 10^{23} \times 1.6 \times 10^{-19} = 3.84 \times 10^{4}$ C to 3.9×10^{4} kC ...3

[no unit or incorrect unit …. (–1)]

QUESTION 11

Recently many manufacturers of fuel ethanol and beverage ethanol switched production to sanitisers consisting of aqueous ethanol solutions with about 70% ethanol. See Figure 17.

(*a*) (*i*) Describe the appearance of ethanol. <u>**2×3**</u>

colourless ...3

liquid ...3

(*ii*) Identify the functional group of the ethanol molecule *and* explain why ethanol is very soluble in water. <u>**3×3**</u>

–OH / hydroxyl ...3

OH group or ethanol polar // hydrogen bonds form ...3

attracted to polar water // between water and ethanol (molecules) ...3

[like dissolves like ...3]

(*iii*) To what homologous series does ethanol belong? <u>**3**</u>

alcohols ...3

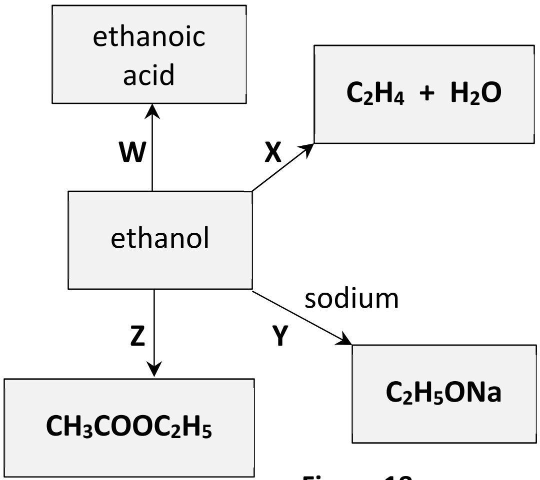


Figure 18

Figure 18 shows some reactions of ethanol.

(*b*) (*i*) Name the type of reaction occurring in each of W, X and Z. <u>**3×3**</u>

W: oxidation ...3

X: elimination / dehydration / reduction ...3

Z: esterification or ester formation / substitution / condensation / dehydration ...3

(*ii*) Identify a suitable reagent for reaction W. <u>**6**</u>

(dilute acidified potassium) permanganate or MnO_4^-/ (acidified sodium or potassium) chromate or CrO_4^{2-}or dichromate or $Cr_2O_7^{2-}$ ...6

(*iii*) Give the IUPAC name for the organic product of reaction Z. <u>**6**</u>

ethyl ethanoate ...6

(*iv*) What property of ethanol is demonstrated in reaction Y? <u>**6**</u>

acidic nature / ability to react as an acid / ability to donate a proton ...6

(*v*) Identify the chemical required to bring about reaction X *and* describe its appearance. **2×3**

Al_2O_3 / aluminium oxide / alumina // sulfuric acid / H_2SO_4 …3

white or off-white powder or granules / white solid // oily or colourless liquid …3

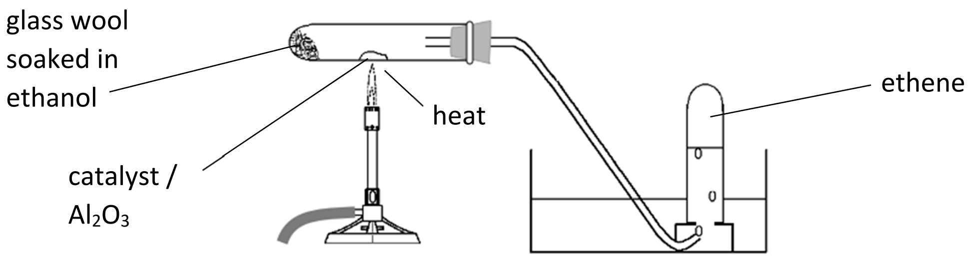
(*vi*) Draw a labelled diagram of the arrangement of apparatus used to carry out reaction X and collect a sample of C_2H_4. **3×3**

horizontal (slanting) test tube with delivery tube shown …3

collection over water shown …3

heat under alumina …3

LABEL:



[Locations of ethanol, ethene, catalyst or chemical required or Al_2O_3 must be labelled]

[Accept apparatus using H_2SO_4 as reagent also]

(*vi*) State a safety precaution taken during this preparation. **6**

avoid suck-back by releasing vacuum or removing delivery tubing from water /
avoid fire – ethanol and ethene flammable /
wear PPE or item of PPE …6

QUESTION 12

Answer any three parts.

Question 12(*a*)
AdBlue, a solution of urea (NH_2CONH_2) in water, is an additive used to remove oxides of nitrogen from the exhaust gases of diesel-fuelled engines. See Figure 19.

When AdBlue is injected into the hot exhaust stream the following reaction occurs producing ammonia:

$$NH_2CONH_2 + H_2O \rightarrow 2NH_3 + CO_2$$

This ammonia reacts simultaneously with nitrogen(II) oxide and nitrogen(IV) oxide in the exhaust stream according to the following balanced equations:

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$$

(*i*) How many moles of ammonia were obtained from the decomposition of all 1620 g urea in a container of AdBlue? **<u>3×2</u>**

M_r (urea) = 60 …2

$\frac{1620}{60}$ = 27 (moles) urea …2

($\Rightarrow$) 54 (moles ammonia) …2

(*ii*) When one such container of AdBlue was used up, 4 moles of O_2 had reacted with NO in the exhaust stream. How many moles of NO_2 could have been removed at the same time by the remaining NH_3? **<u>3×3</u>**

(4 moles $O_2 \Rightarrow$) 16 (moles NO) …3

(16 moles NH_3 react with NO $\Rightarrow$ 54 – 16 =) 38 moles NH_3 (react with NO_2) …3

($\Rightarrow$) 28.5 (moles NO_2) …3

(*iii*) How many water molecules were produced as a result of removing the NO? **<u>2×2</u>**

16 moles NO $\Rightarrow$ 24 moles water …2

($24 \times 6.0 \times 10^{23}$) = 1.44×10^{25} …2

(*iv*) What environmental problem is caused by excess oxides of nitrogen in air? **<u>3</u>**

acid rain / smog / greenhouse effect / global warming / damage to ozone layer …3

[pollution …(1)]

Question 12(*b*)
Define

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

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

(*ii*) atomic mass, **<u>3</u>**

sum (combined number) of protons and neutrons (in the nucleus of an atom) /
number of nucleons in the nucleus of an atom …3

(*iii*) relative atomic mass. **<u>2×3</u>**

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

Silicon has three naturally occurring stable isotopes with mass numbers 28, 29 and 30. Silicon–28 occurs with 92.2% abundance, silicon–29 with 4.7% abundance and silicon–30 with 3.1% abundance. Only traces of other radioactive isotopes exist.

Use this data to calculate the relative atomic mass of silicon, correct to two decimal places. **<u>2×3, 4</u>**

(28 × 92.2) + (29 × 4.7) + (30 × 3.1) / 2581.6 + 136.3 + 93 …3
= 2810.9 …3
(2810.9 ÷ 100 = 28.109 ⇒ A_r =) 28.11 …4
[Not rounded or incorrectly rounded …(–1)]

Question 12(*c*)

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)]

Describe how electronegativity values can be used to predict the type of bond that occurs between a pair of atoms. **3×3**

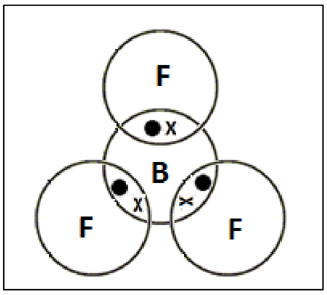
ionic bond with significant difference in electronegativity values / ionic bond with difference in electronegativity values > or ≥ 1.7 ...3

non-polar or pure covalent bond with insignificant or small or zero difference in electronegativity values / non-polar or pure covalent bond with difference in electronegativity values < or ≤ 0.4 ...3

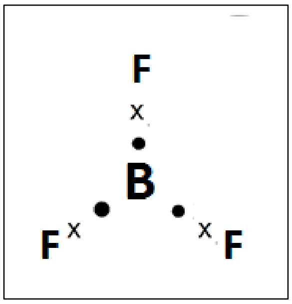
polar covalent bond with modest or some difference in electronegativity values / polar or covalent bond with difference in electronegativity values > or ≥ 0.4 and< or ≤ 1.7 ...3

[Electronegativity instead of electronegativity difference (–3) but once only in Describe.]

Draw a dot and cross diagram to show the bonding in a molecule of BF_3. **3**



/



3 bond pairs and no lone pairs in valence shell boron ...3

Predict

(*i*) the shape, **2**

trigonal planar / triangular planar [diagram insufficient] ...2

(*ii*) the bond angle, in a BF_3 molecule. **2**

120° ...2

[Correct angle for incorrect shape not acceptable.]

Question 12 (*d*)

State Hess's law. **2×3**

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

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)][evolved instead of involved …(–1)]

C_xH_{2x} is a gaseous fuel that burns completely in oxygen according to the following balanced equation.

$$C_xH_{2x\,(g)} + \frac{3x}{2}O_{2\,(g)} \rightarrow xCO_{2\,(g)} + xH_2O_{(l)} \qquad \Delta H = -1412 \text{ kJ}$$

Use Hess's law and the following information to deduce the value of x in the formula C_xH_{2x}.

$$xC_{(s)} + xH_{2\,(g)} \rightarrow C_xH_{2x\,(g)} \qquad \Delta H = 52 \text{ kJ}$$
$$H_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow H_2O_{(l)} \qquad \Delta H = -286 \text{ kJ}$$
$$C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} \qquad \Delta H = -394 \text{ kJ}$$

5×2

$$C_xH_{2x\,(g)} \rightarrow xC_{(s)} + xH_{2\,(g)} \qquad \Delta H = -52 \text{ kJ}$$ ...2
$$xH_{2\,(g)} + \frac{x}{2}O_{2\,(g)} \rightarrow xH_2O_{(l)} \qquad \Delta H = -286x \text{ kJ}$$ ...2
$$xC_{(s)} + xO_{2\,(g)} \rightarrow xCO_{2\,(g)} \qquad \Delta H = -394x \text{ kJ}$$ ...2

$$C_xH_{2x\,(g)} + \frac{3x}{2}O_{2\,(g)} \rightarrow xCO_{2\,(g)} + xH_2O_{(l)} \qquad \Delta H = -1412 \text{ kJ}$$ ...2

$$-1412 + 52 = -286x - 394x \Rightarrow x = 2$$ ...2

[Accept answer deduced by trial and error.]