Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2023

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 units / 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 *third* law of motion. **2×3**
for every action or force …3
there is an equal and opposite reaction or force …3

(*b*) Dublin Port Tunnel is 4.5 km in length and has an 80 km per hour speed limit. Cameras at the entry and exit points are used to determine the average speed of a vehicle driving through the tunnel. What is the minimum time, in minutes, to drive through the tunnel without exceeding 80 km per hour on average? **2×3**
time = total distance ÷ (average) speed / $t = \frac{s}{v}$ / (t =) $\frac{4.5}{80}$ / (t =) $\frac{4.5}{1.3333}$ …3
0.05625 hour $\Rightarrow$ 3.375 minutes / …3
[if 80 km per hour given instead of km per minute, allow calculation based on 1.3, 1.33, 1.333, to give 3.462, 3.383, 3.376, respectively]

(*c*) State the principle of conservation of momentum. **2×3**
[1]when no external force acts or in a closed system, (total) momentum before (a collision) equals //
[2]when no external force acts or in a closed system, (total) momentum remains or is //
[3]when no external force acts or in a closed system, $m_1u_1 + m_2u_2 =$ …3
[1]momentum after // [2]constant // [3]$m_1v_1 + m_2v_2$ or $(m_1 + m_2)v$ …3
['external force' or 'closed system' omitted (–1)]

(*d*) When struck once with a hammer, a nail of mass 0.018 kg was given a horizontal initial velocity of 8.0 m s^{-1} and as a result its point penetrated horizontally 0.02 m into a block of wood before coming to rest. Calculate the average force exerted by the wood on the nail. **3, 2, 1**
$v^2 = u^2 + 2as$ or $0^2 = 64 + 2 \times a \times 0.02$ …3
($\Rightarrow a =$) (−)1600 m s^{-2} …2
($F = ma = 0.018 \times 1600 =$) 28.8 (N or kg m s^{-1}) …1

(*e*) How does Brownian motion provide evidence for the kinetic theory? **6**
shows particles in rapid or random or zig-zag motion / shows particle collisions / shows particulate nature of matter …6

(*f*) Explain how sample X of a liquid and sample Y of the *same* liquid could have the same temperature but contain different quantities of heat. **6**
different mass or different volume …6

(*g*) A small gas cylinder of volume 7 × 10^{-5} m^3 contained 0.75 moles of carbon dioxide at a temperature of 293 K. What was the pressure, in Pa, of the gas inside the cylinder? **4, 2**
$PV = nRT$ / $P \times 7 \times 10^{-5} = 0.75 \times 8.31 \times 293$ …4
($P =$) 2.60 (or 2.61) × 10^7 (Pa) …2

(*h*) What type of mirror forms an image at infinity of an object placed at its focal point? **6**
concave or converging …6

(*i*) Arrange the following forms of electromagnetic radiation in order of *increasing* wavelength.
gamma waves infrared radiation x-rays violet light **6**
gamma, x-rays, violet light, infra-red …6
[allow …3 for reverse order] [allow …3 if 1st and 4th correct]

(*j*) What is meant by the diffraction of a wave? **4, 2**

spreading out of a wave or bending of a wave …4

after passing or as it passes an obstacle or through a gap or into geometrical shadow of obstacle …2

(*k*) Figure 2 represents a longitudinal wave moving to the right. A = 12 cm. What is the wavelength of the wave? **6**

4 (cm) …6

(*l*) Write an equation to define capacitance. **6**

(*C* =) $\frac{Q}{V}$ / (capacitance is) ratio of charge to potential difference …6

[allow …3 for *C* = $\frac{\varepsilon A}{d}$]

(*m*) What is a magnetic field? **2×3**

space or region around a magnet or electromagnet or moving electric charge

or current-carrying conductor …3

where its force acts / where its effects can be detected / where compass needle or iron filings respond …3

(*n*) What is the combined resistance of four 9 Ω resistors connected in parallel? **4, 2**

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$ / $\frac{1}{R} = \frac{1}{9} + \frac{1}{9} + \frac{1}{9} + \frac{1}{9}$ / $\frac{1}{R} = \frac{4}{9}$ …4

$\Rightarrow$ *R* = 2.25 (Ω) …2

(*o*) Identify the type of device that changes a 230 V a.c. supply to a 5 V a.c. supply. **6**

transformer ...6

(*p*) Why are high voltages used to transmit electrical energy over long distances? **6**

economical / less power lost / less heat (lost) / smaller current in wires / wires used can be thinner, etc. …6

(*q*) What change takes place in an unstable nucleus when it emits a beta particle? **4, 2**

a neutron changes into a proton / atomic number increases by 1

and an electron (that is emitted) first correct …4, second, …2

[allow 'a proton changes into a neutron and a positron (that is emitted)' …4 + …2]

(*r*) Figure 3 represents the last two stages of a radioactive decay chain. Identify the last isotope of the chain which is formed when a bismuth–211 nucleus emits an alpha particle, and then its daughter nucleus (D) emits a beta particle. **2×3**

lead / Pb …3

207 …3

[allow mercury / Hg / 207, consistent with positron emission …3 + …3]

[allow D = Thallium / Tl−207 for …3]

QUESTION 2

(*a*) Define (*i*) force, **6**

causes (or tends to cause) acceleration (motion) or change of direction or change of shape or changes an existing motion in magnitude or direction …6

[allow ….6 for push or pull or interaction between two objects or causes reaction or (F =) ma]

(*ii*) work. **2×3 or 6**

[1]when point of application of force // [2]application of a force // [3]energy transferred when a force …3

[1]moves in direction of force // [2]over a distance // [3]acts over a distance …3

or or

force × displacement / force × distance / Fs / Fd / change in kinetic energy or (gravitational) potential energy …6

(*iii*) What is the relationship between work and kinetic energy? **3**

work converted into kinetic energy (when force causes movement) / $Fs = ½mv^2$ / $Fs = ½mv^2 – ½mu^2$ …3

[allow 'energy is the ability to do work' for …1]

(*iv*) What quantity is defined as the rate of doing work? **3**

power …3

Figure 4 shows how an architect incorporated an access ramp into a building design. A child of mass 21.0 kg used the ramp to enter the building, the floor of which is 2.5 m vertically above the ground.

(*v*) State the principle of conservation of energy. **6**

energy is neither created nor destroyed but can be converted from one form into another …6

[allow $E_k + E_p$ = constant …6] [Allow $\Delta E_k + \Delta E_p = 0$ …6]

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

(*vi*) What was the potential energy gained by the child who entered the building? **4, 2**

(E =) mgh / (E =) 21 × 9.8 × 2.5 …4

(E =) 514.5 J …2

[no unit or incorrect unit (–1)]

(*vii*) For people entering and leaving the building, what is a specific advantage of a long, gently inclined ramp over a steeply sloped one? **3**

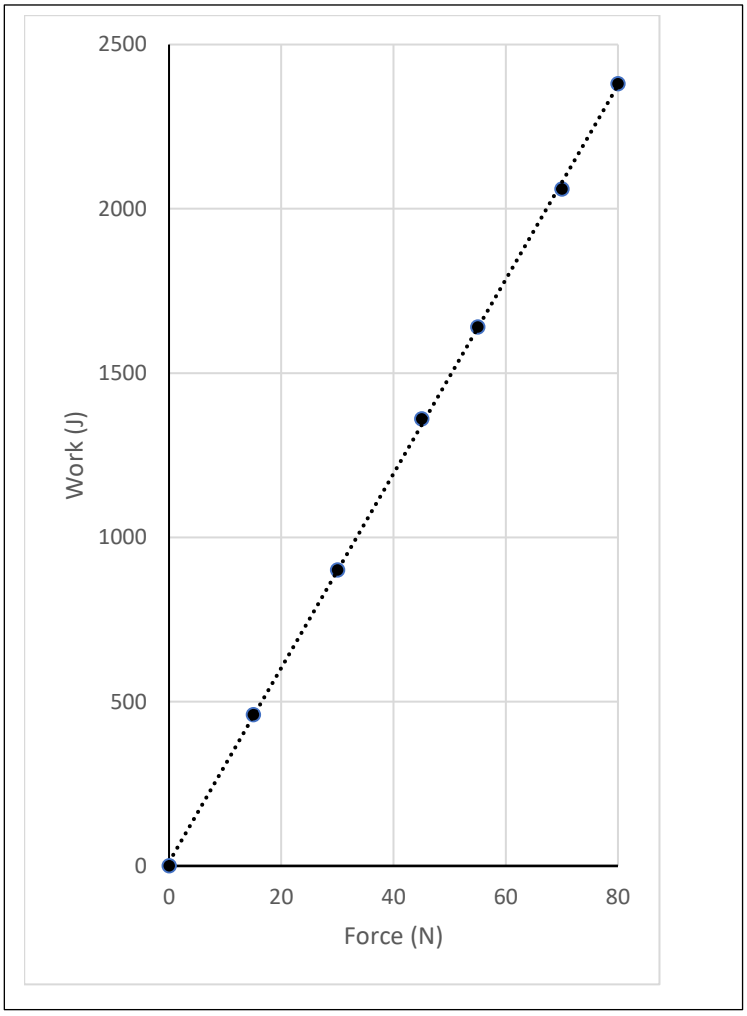
less force needed (to do same work) / less force or easier to push a buggy or wheelchair / less acceleration leaving / easier to control or resist weight of buggy or wheelchair on descending ramp / it is safer, etc. …3

(*b*) The table below gives the work done when different forces were applied to a 32.0 kg mass to produce the same displacement, *s*, in each case.

Force (N)	0	15	30	45	55	70	80
Work (J)	0	460	900	1,360	1,640	2,060	2,380

(*i*) Plot a graph, on graph paper, to show the variation of work with force (x-axis). **4×3**

axes labelled work or joules or J, and force or newtons or N …3
axes drawn with appropriate scales …3
six points correctly plotted …3
points connected by straight line through origin ...3
[if not on graph paper (–3)] [axes reversed (–3)]



(*ii*) What quantity can be determined from the slope of the graph? **3**

displacement / distance / *s* …3

(*iii*) Find the value of this quantity from your graph. **2×3**

Work from candidate's chosen points.
e.g.
$\frac{y_2-y_1}{x_2-x_1} = \frac{1500-1000}{50-34} / \frac{\text{rise}}{\text{run}} = \frac{1500-1000}{50-34}$ …3
(slope = distance =) 31.25 m ...3
[no unit or incorrect unit (–1)]

or or

if work given on x-axis, marks may be earned
e.g.
$\frac{y_2-y_1}{x_2-x_1} = \frac{50-34}{1500-1000} / \frac{\text{rise}}{\text{run}} = \frac{50-34}{1500-1000}$ …3
(slope = 1/0.032 ⇒ distance =) 31.25 m ...3
[no unit or incorrect unit (–1)] [allow N J^{-1} for unit only if work on x-axis]

(*iv*) From your graph, or otherwise, find the work done if a force of 65 N had been applied. **…6**
from graph: 65 N gives 1925 [1900 – 1950] (J) / using $W = Fs$: = 65 × 31.25 = 2031.25 (J) …6

(*v*) What was the final speed of the 32.0 kg mass, initially at rest, after 65 N was applied over *s*, assuming any other forces can be ignored? **3, 2, 1**
work done = E_K or $\frac{1}{2} mv^2$ …3
1925 = $\frac{1}{2} mv^2$ or $\frac{1}{2} \times 32.0 \times v^2$ …2
(v =) 10.9 – 11.0 m s^{-1} …1
[no unit or incorrect unit (–1)]

or or

(acceleration = $F \div m$ = 65 ÷ 32 =) 2.03(125) m s^{-2} …3
($v^2 = u^2 + 2as \Rightarrow$) v^2 = (2 × 2.03(125) × 31.25 =) 126.953(125) …2
(v =) 11.2 – 11.3 m s^{-1} …1
[no unit or incorrect unit (–1)]

or or

(acceleration = $F \div m$ = 65 ÷ 32 =) 2.03(125) m s^{-2} …3
$s = ut + \frac{1}{2}at^2 \Rightarrow t$ = 5.55 (s) ...2
($v = u + at$ = 2.03(125) × 5.55 =) 11.2 – 11.3 m s^{-1} …1
[no unit or incorrect unit (–1)]

QUESTION 3

(*a*) (*i*) State Charles' law. **3×3**

volume is (directly) proportional to absolute temperature / volume is (directly) proportional to temperature on Kelvin scale / $V \propto T$ / $\frac{V}{T}$ = constant or $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ / volume increases by a factor of 1/273 for every one degree (Celsius, or one K) rise in temperature ...3

for a fixed mass of gas …3

at constant pressure …3

[if 'varies' given rather than 'proportional', it must be 'varies directly' but 'directly' not required with 'proportional']

A basketball filled with air, like that shown in Figure 5, had a volume of 7,100 cm^3 at 293 K.

(*ii*) By how much, to the nearest cm^3, did the ball shrink, when left outside on a cold night at 273 K? **3×3**

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ / $\frac{7100}{293} = \frac{V_2}{273}$ …3

(V_2 =) 6615.4 (cm^3) or 6615 (cm^3) …3

(7100 – 6615.4 = 484.6) $\Rightarrow$ 485 (cm^3) …3

The data in the table below show the pressure (*P*) of a fixed mass of gas recorded at a number of different temperature (*T*) values. The volume is constant.

***T* (K)**	**100**	**150**	**200**	**273**	**325**	**350**	**400**
***P* (kPa)**	**29**	**44**	**61**	**83**	**98**	**106**	**120**

(*iii*) Plot a graph to show the variation of *P* with *T*. **4×3**

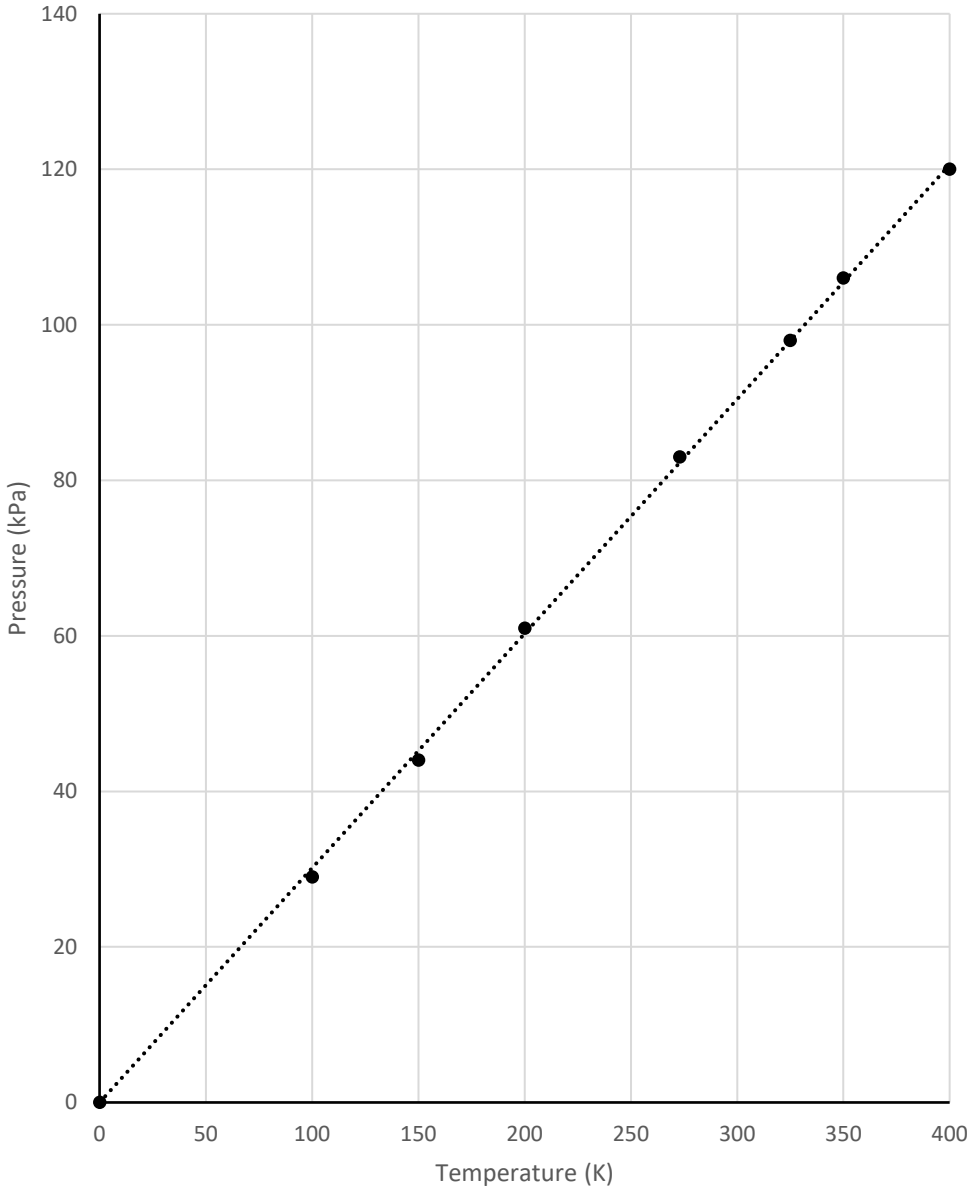
axes labelled P or pressure or kPa and *T* or temperature or K …3

axes drawn with appropriate scales …3

six points correctly plotted …3

points joined by straight line ...3

[if not on graph paper (–3)] [allow axes reversed]



(*iv*) What relationship between pressure and temperature is established by your graph? **4, 2**

pressure proportional to (Kelvin) temperature …4

Justify your answer.

straight line …2

(*b*) (*i*) What is meant by the triple point temperature of water? **6**

the temperature at which steam or water vapour, (liquid) water, and ice co-exist / three states of water present at same time …6

[allow 0.01 °C or 273.16 K for …3]

(*ii*) The triple point of water is one of two fixed points used to define temperature on the Kelvin scale. What is the other fixed point? **6**

absolute zero / 0 K / –273.15 °C …6

(*iii*) The constant volume gas thermometer uses pressure as its thermometric property. Explain the underlined term. **3**

changes (measurably) as temperature changes …3

(*iv*) Why is a constant volume gas thermometer used as a standard thermometer? **6**

based on *PV* standard thermometric property / independent of gas used /
used to calibrate other thermometers / accurate / wide range / sensitive /
thermometers based on different thermometric properties give different readings for same temperature /
different thermometers give different readings for same temperature …6

Temperature T on the Kelvin scale is defined by the expression $T = 273.16\left(\frac{P_T}{P_{tp}}\right)$ where P_T and P_{tp} are pressure readings from a constant volume gas thermometer at temperature T and at the triple point temperature of water, respectively.

(*v*) Calculate the pressure at the triple point temperature in a constant volume gas thermometer that gave a pressure reading of 9.40×10^4 Pa at 313.15 K. **2, 1**

$T = 273.16\frac{P_T}{P_{tp}}$ / $P_{tp} = 273.16\frac{P_T}{T}$ / $P_{tp} = 273.16\frac{9.40 \times 10^4}{313.15}$ ..2

(P_{tp} =) 8.20×10^4 Pa …1

[no unit or incorrect unit (−1)]

(*vi*) Write an expression for the relationship between temperature on the Kelvin scale *T* and temperature on the Celsius scale θ. **6**

$T = \theta + 273(.15)$ or $\theta = T - 273(.15)$ …6

[if '273.16' given in either expression (−1)]

QUESTION 4

(*a*) (*i*) What is refraction of light? **4, 2**

bending (of light) ...4

as it passes from one medium into another …2

(*ii*) State Snell's law of refraction. **6 or 2×3**

$\frac{\sin i}{\sin r}$ = constant or *n* or *k* or μ …6

or or

^{1}sine of angle of incidence proportional to // ^{2}sin*i* $\propto$ …3

^{1}sine of angle of refraction // ^{2}sin*r* …3

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

(*iii*) Describe, with the aid of a labelled diagram, an experiment to measure the refractive index of a rectangular block of glass. **3×3**

incident ray and refracted ray using pins or ray box or laser …3

measure angle of incidence and angle of refraction …3

average of values of sin*i* ÷ sin*r* / refractive index is slope of graph of sin*i* versus sin*r* …3

[no diagram or diagram with no labels (–3)]

State whether a change occurs in **3×3**

(*iv*) its speed,

yes …3

(*v*) its frequency,

no …3

(*vi*) its wavelength, when a light wave undergoes refraction.

yes …3

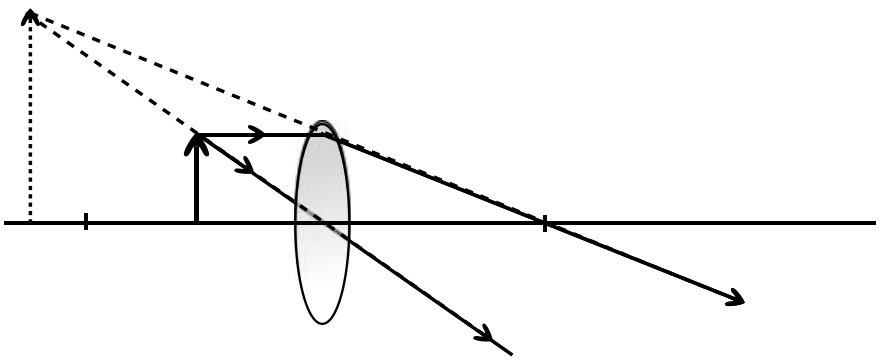
(*b*) Images are formed by lenses as a result of the refraction of incident rays.

(*i*) Distinguish between a real and a virtual image. **2×4**

real: caused by actual intersection of light rays / can be formed on a screen / object on one side of lens and image on other side …4

virtual: caused by apparent intersection of light rays / cannot be formed on a screen / object and image on same side of lens …4

(*ii*) Draw a diagram to show the formation of a virtual, upright, magnified image by a convex (converging) lens. **2×2**



2 rays refracted …2

virtual paths to give upright, magnified image …2

(*iii*) An object is placed 4 cm from a convex (converging) lens. A virtual image is formed 5 cm from the lens. Calculate the focal length of the lens. **4, 2**

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ / $\frac{1}{f} = \frac{1}{4} + \frac{1}{-5}$ / $\frac{1}{f} = \frac{1}{4} - \frac{1}{5}$ …4

($\Rightarrow \frac{1}{f} = \frac{1}{20}$ and f =) 20 cm …2

[no unit or incorrect unit (−1)]

(*c*) Irish scientist John Tyndall demonstrated around 1870 how light could be 'piped' along a stream of water. A modern version of this demonstration using a laser beam as the light source is shown in Figure 6.

(*i*) Identify the phenomenon that confines the laser light to the stream of water. **2×4**

total internal …4

reflection …4

(*ii*) What is meant by the critical angle of a material? **2×4**

angle of incidence (in the denser medium) …4

when the angle of refraction is 90° / beyond which rays are totally reflected (at boundary) …4

(*iii*) Calculate the critical angle for water if the refractive index for water is 1.33. **2×1**

$n = \frac{1}{\sin c}$ or $1.33 = \frac{1}{\sin c}$ or $\sin c = \frac{1}{1.33}$ or sin*c* = 0.7519 …1

($\Rightarrow$ *n* =) 48.8° or 49° …1

[no unit or incorrect unit (−1)]

QUESTION 5

An electric current is the flow of charge through a conductor.

(a) (*i*) Identify the charge carriers when the conductor is a copper wire. **6**

electrons …6

(*ii*) Distinguish between a *direct* current and an *alternating* current. **2×3**

direct:

flows in one direction only …3

alternating:

reverses direction (of flow) periodically …3

[correct diagrams allow …3 + …3]

(*iii*) Describe how you would demonstrate the magnetic effect of a direct current. **3×2**

current-carrying wire or current-carrying coil …2

iron filings / compass / paper clip …2

pattern or circle / deflection …2

(*iv*) Identify another possible effect of a current flowing in a conductor. **6**

heating / chemical …6

(*b*) (*i*) State Ohm's law. **2×3**

[1]current (in a conductor) proportional to // [2]$I \propto$ // [3]voltage or potential difference proportional to // [4]$V \propto$ // [5]V = …3

[1]potential difference or voltage at constant temperature // [2]V at constant temperature // [3]I at constant temperature // [4]current (in a conductor) at constant temperature // [5]IR at constant temperature …3

['at constant temperature' omitted (–1)]

Calculate the current flowing

(*ii*) in a 4.0 Ω resistor connected to a 9.0 V supply, **4, 2**

$V = IR$ / $9 = I \times 4$ …4

($\Rightarrow I =$) $9 \div 4 =$) 2.25 – 2.3 A or amps …2

[no unit or incorrect unit (–1) but penalise once only for (*ii*) and (*iii*) and (*iv*)]

(*iii*) in the element of a 2.5 kW kettle connected to a 230 V supply, **4, 2**

$P = VI$ / $2500 = 230 \times I$ …4

($\Rightarrow I = 2500 \div 230 =$) 10.869 – 10.9 A …2

[no unit or incorrect unit (–1) but penalise once only for (*ii*) and (*iii*) and (*iv*)]

[allow …5 for 0.01 A if kW not changed to W]

(*iv*) in the 29.4 Ω element of a 1.8 kW toaster when it is switched on. **4, 2**

$P = RI^2$ / $1800 = 29.4 \times I^2$ …4

($\Rightarrow I^2 = 1800 \div 29.4 \Rightarrow I =$) 7.82 A …2

[no unit or incorrect unit (–1) but penalise once only for (*ii*) and (*iii*) and (*iv*)]

[allow …2 for 0.24 A or 0.25 A if kW not changed to W]

or or

$P = VI$ / $1800 = 230 \times I$ (230 V assumed here) …4

($\Rightarrow I = 1800 \div 230 =$) 7.8 A …2

[no unit or incorrect unit (–1) but penalise once only for (*ii*) and (*iii*) and (*iv*)]

[allow …2 for 0.0078 A or 0.008 A if kW not changed to W]

(*c*) A dynamo, like that shown in Figure 7, produces a direct current by electromagnetic induction.

(*i*) Identify the parts labelled A, B, C. **3×2**

A: coil / armature …2

B: carbon / brush …2

C: split ring / commutator …2

(*ii*) What is the main energy conversion taking place as the current is generated? **2×3**

mechanical energy or kinetic energy …3

to electrical energy …3

[reversed …3]

(*iii*) State one way of increasing the size of the current generated. **6**

increase strength of magnet / rotate faster / increase number of turns of coil / make coil larger / reduce resistance of circuit / reduce load …6

QUESTION 6

Answer any two of the parts (a), (b), (c), (d). Each part carries 33 marks.

Question 6 (*a*)

(*i*) Distinguish between the mass and the weight of an object. **6, 3**

- mass is the amount of matter in an object / mass is the measure of resistance to movement / mass is the measure of inertia / mass measured in kilograms or kg / mass does not change with position / mass is a scalar quantity
- weight is the force of gravity on an object / weight is mass × acceleration due to gravity / weight is mass × local acceleration of free fall / $W = mg$ / weight measured in newtons or N / weight may change with position / weight is a vector quantity

first correct from either …6
second correct from other …3

(*ii*) State Newton's law of universal gravitation. **2×3 or 6**

force between (any) two (point) masses is proportional to the product of the masses ...3
and inversely proportional to the square of the distance between them or their centres …3
['sum' instead of 'product' (−3)] ['square of distance' omitted (−3)]

or or

$F = \frac{GMm}{d^2}$ / $F \propto \frac{Mm}{d^2}$ …6

(*iii*) Derive an expression for the relationship between *g*, the acceleration due to gravity, and *G*, the gravitational constant. **2×3**

$F = \frac{GMm}{d^2}$ and $F = mg$ / $\frac{GMm}{d^2} = mg$ …3

$g = \frac{GM}{d^2}$ or $G = \frac{gd^2}{M}$ …3

(*iv*) Pluto is a dwarf planet in our solar system. A small mass, released from rest close to the surface of Pluto, radius1.19 × 10^6 m, would experience an acceleration of 0.620 m s^{-2} towards the centre of Pluto. Calculate the mass of Pluto. **6, 3**

$\frac{GM}{d^2} = g$ / $\frac{6.6742 \times 10^{-11} M}{(1.19 \times 10^6)^2} = 0.620$ …6

(M =) 1.3(15) × 10^{22} kg …3
[no unit or incorrect unit (−1)]
[take 1.3(15) × 10^{22} kg with incorrect power of 10 as slip error, ∴ (−1)]

(*v*) Pluto's largest moon is Charon. When an object is 1.45 × 10^7 m from the centre of Pluto and 5.10 × 10^6 m from the centre of Charon, as shown in Figure 8, the gravitational forces due to Pluto and Charon cancel. Calculate the mass of Charon. **2, 1**

$\frac{GM}{d^2} = \frac{Gm}{x^2}$ / $\frac{M}{d^2} = \frac{m}{x^2}$ / $\frac{1.315 \times 10^{22}}{(1.45 \times 10^7)^2} = \frac{m}{(5.1 \times 10^6)^2}$ …2

(m =) 1.6(26) × 10^{21} kg …1
[no unit or incorrect unit (−1)]
[take 1.6(26) × 10^{21} kg with incorrect power of 10 as slip error, ∴ (–1)]

Question 6 (*b*)

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

packet or unit of light or of electromagnetic energy / massless particle of energy / elementary or fundamental particle of electromagnetic radiation …6

[no mention of 'light' or 'electromagnetic' (−1)]

What is meant by (*ii*) the frequency, **3**

number of waves or oscillations or periods passing a point per second or $f = \frac{1}{T}$ …3

[incorrect time unit (−1)]

(*iii*) the wavelength, of a wave? **3**

distance between two (successive) corresponding points (on a wave) / distance between two (successive) crests / distance from trough to (next) trough / distance travelled (by a wave) in one period of the cycle / $\lambda = \frac{c}{f}$ …3

[allow labelled diagram]

(*iv*) Calculate the wavelength of the wave associated with photons of energy 7.5×10^{-19} J. **4×3, or 2×6**

$E = hf$ / $7.5 \times 10^{-19} = 6.626 \times 10^{-34} \times f$ …3

(f =) $7.5 \times 10^{-19} \div 6.626 \times 10^{-34} = 1.13 \times 10^{15}$ Hz …3

$c = f\lambda \;/\; \lambda = \frac{c}{f} \;/\; \lambda = \frac{3\times10^{8}}{1.13\times10^{15}}$ …3

(λ =) 2.65×10^{-7} m / 265 nm …3

[no unit or incorrect unit (−1)]

or or

$E = h\frac{c}{\lambda}$ / $7.5 \times 10^{-19} = 6.626 \times 10^{-34}(\frac{3\times10^{8}}{\lambda})$ …6

(λ =) 2.65×10^{-7} m / 265 nm …6

[no unit or incorrect unit (−1)]

Some photons cause electrons to be released from the surface of a metal.

(*v*) Identify this phenomenon. **6**

photoelectric effect …6

(*vi*) Explain why only some photons cause this phenomenon. **3**

minimum energy or minimum frequency required …3

Question 6 (*c*)

(*i*) In terms of of subatomic particles, how does a positive charge arise on an object? **3**

loss or emission of electron(s) / more protons than electrons …3

Draw separate diagrams to show

(*ii*) the distribution of positive charge on a metal sphere mounted on an insulated stand, **6**

charges evenly distributed around the sphere …6

(*iii*) the electrical field around the sphere. **2×3**

radial field lines …3

direction away from charge / from sphere …3

(*iv*) Give one use for a gold-leaf electroscope. **6**

to detect charge / to estimate size of charge / to compare charge / to identify charge as positive or negative / to determine whether a material is an insulator or a conductor / to measure potential / to detect radioactivity / to show the photoelectric effect, etc. …6

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

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

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

or or

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

$[F = \frac{q_1q_2}{d^2}$ (–1)]

(*vi*) *F* is the force between two insulated metal spheres, with charges +*Q* and –*Q* respectively, and their centres separated by a distance *d*. In terms of *F*, what was the force between the spheres when the distance between their centres was increased to 3*d*? **6**

F/9 / F ÷ 9 …6

[allow …3 for 9*F*]

Question 6 (*d*)

Categorise each of the following nuclear reactions as either a fission or a fusion reaction:

(*i*) $^{235}_{92}\mathbf{U} + {}^{1}_{0}\mathbf{n} \rightarrow {}^{92}_{36}\mathbf{Kr} + {}^{141}_{56}\mathbf{Ba} + 3{}^{1}_{0}\mathbf{n}$ **+ energy,** **6**

fission …6

(*ii*) $2{}^{3}_{2}\mathbf{He} \rightarrow {}^{4}_{2}\mathbf{He} + 2{}^{1}_{1}\mathbf{H}$ **+ energy.** **6**

fusion …6

(*iii*) Explain why a nuclear chain reaction could arise in uranium–235 as a result of reaction (*i*). **2, 1**

neutron(s) produced (by fission of uranium) …2

cause(s) (more) fission (of other uranium atoms) …1

(*iv*) Give one application of fission reactions. **6**

electricity generation or power generation or nuclear reactor / bomb or weapon / to make radioactive isotopes / to investigate structure of crystals, etc. …6

(*v*) Use data from page 83 of the *Formulae and Tables* booklet to calculate the mass loss in unified atomic mass units (u) for each He–4 nucleus produced in (*ii*) above. **3×3**

(2 × 3.016029 =) 6.032058 …3

(4.002603 + (2 × 1.007825)) = 6.018253 …3

(6.032058 – 6.018253) = 0.013805 …3

[rounding to less than 6 decimal places (–1) but once only]

Then use data from page 47 of *Formulae and Tables* to calculate the energy in joules (J) released for each of these He–4 nuclei produced. **3×1**

(0.013805 × 1.6605402 × 10^{-27}) = 2.2923757 × 10^{-29} (kg) …1

$E = mc^2$ / E = 2.2923757 × 10^{-29} × (2.99792458 × 10^{8})^2 …1

(E =) 2.060284532 × 10^{-12} (J) …1

[rounding *c* or *u* from page 47 or elsewhere to less than 6 decimal places (–1) but once only]

QUESTION 7

Any eleven parts **11×6**

(*a*) How many (*i*) neutrons, **4, 2**

5 (neutrons)

(*ii*) electrons, are there in a $^{9}_{4}\mathbf{Be}^{2+}$ ion?

2 (electrons) first correct …4, second…2

(*b*) Figure 9 represents the 9 *outer* electrons in the 4*s* and 3*d* sub-levels of a neutral atom of a certain transition element in its ground state. What is the element? **6**

cobalt / Co …6

(*c*) Calculate a value for the relative atomic mass of a sample of neon composed of 91% neon–20 and 9% neon–22. **2×3**

(91 × 20) + (9 × 22) / 1820 + 198 / 2018 …3

2018 ÷ 100 = 20.18 or 20.2 …3

(*d*) Diamond and graphite are allotropes of carbon.

What are allotropes? **2×3**

different (physical) forms …3

of the same element …3

(*e*) Write the chemical formulae for iron(II) sulfide and magnesium hydroxide. **4, 2**

FeS

$Mg(OH)_2$ first correct …4, second…2

(*f*) Identify the energy change associated with the following balanced equation:

$X_{(g)} \rightarrow X^{+}_{(g)} + e^{-}$ **2×3**

first …3

ionisation (energy) …3

(*g*) Find the chemical formula of the oxide of copper (Cu_xO) that contains 11.2% by mass of oxygen. **2×3**

(11.2 ÷ 16 =) 0.7 (moles O) and (88.8 ÷ 63.5 =) 1.4 (moles Cu) …3

(1.4 : 0.7 = 2 : 1 ⇒) Cu_2O or $x = 2$ …3

(*h*) Identify *(i)* the conjugate acid, **2×3**

H_2SO_3 …3

[any charge shown (–1)]

***(ii)* the conjugate base, of HSO_3^-.**

SO_3^{2-} …3

[no charge or incorrect charge (–1)]

(*i*) Copy, complete and balance the equation: HCl + $CaCO_3$ → **2×3**

$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$ formulae of products …3

balancing …3

[allow 'H_2CO_3' instead of '$H_2O + CO_2$']

(*j*) A nicotine skin patch like the one shown in Figure 10 contains 14 mg of nicotine ($C_{10}H_{14}N_2$).
How many moles of nicotine are there in the patch? **4, 2**

M_r nicotine = 162

($\frac{0.014}{162}$ =) 8.64×10^{-5} (mole) first correct …4, second…2

[incorrect power of 10 (−1)]

(*k*) Arrange the elements Ag, Cu, Fe, Na and Zn in order of their decreasing tendency to donate electrons. **6**

Na, Zn, Fe, Cu, Ag …6

[reversed …3]

[Na first, Ag last …3]

(*l*) Ice (solid H_2O) and dry ice (solid CO_2) are molecular crystals.
How are the molecules held together in a crystal **4, 2**
(*i*) ice,

hydrogen bonding / H-bonds

(*ii*) dry ice?

Van der Waals forces / London forces / dispersion forces / temporary dipole-dipole forces

first correct …4, second …2

(*m*) What is an amphoteric oxide? Give an example. **2×3**

has both acidic and basic properties / reacts or acts as an acid or as a base …3

water or H_2O / zinc oxide or ZnO / aluminium oxide or Al_2O_3, etc. …3

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

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

is dissolved in excess solvent or in excess water / is fully dissolved …3

['one mole' omitted (–1)] ['evolved' rather than 'involved' (–1)]

(*o*) Figure 11 shows the structure of a toluene molecule.
What is the molecular formula of toluene? **6**

C_7H_8 …6

[$C_6H_5CH_3$ (−1)]

(*p*) Name the homologous series of hydrocarbons that has the general formula C_nH_{2n+2}, where $n \geq 1$. **6**

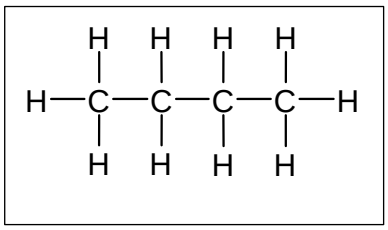
alkanes …6

(*q*) What colour change would you expect to observe if a little of Fehling's reagent were heated gently in the presence of a few drops of an aldehyde? **2×3**

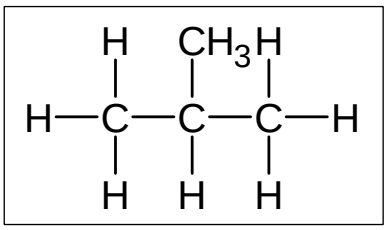
blue to …3

(brick) red precipitate …3

(*r*) Draw the two possible structures of a molecule with formula C_4H_{10}. **4, 2**



and



[Hs need not be explicitly shown]

first correct …4, second …2

QUESTION 8

(*a*) Distinguish between

(*i*) an element and a compound, **2, 1**

element:

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

compound:

composed of two or more elements chemically combined or bonded together first correct …2, second …1

(*ii*) an atom and a molecule, **2, 1**

atom:

smallest particle of an element

molecule:

smallest particle of an element or of a compound that can exist independently /
two or more atoms joined chemically or bonded together first correct …2, second …1

(*iii*) ionic and covalent bonding. **2×6**

ionic:

involves transfer of electrons / involves attraction between oppositely charged ions /
arises where difference in electronegativity values (between the bonding atoms) > 1.7 …6

covalent:

involves sharing of electrons / involves mutual attraction for shared electrons /
arises where difference in electronegativity values (between the bonding atoms) ≤ 1.7 …6

(b) (*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)]

Write the *s*, *p* electron configuration for

(*ii*) a lithium atom, **3**

$1s^2\ 2s^1$ / [He] $2s^1$ …3

(*iii*) a chlorine atom. **3**

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ / [Ne] $3s^2\ 3p^5$ …3
[allow $2p_x^2\ 2p_y^2\ 2p_z^2$ for $2p^6$, and $3p_x^2\ 3p_y^2\ 3p_z^1$ for $3p^5$]

(*b*) Lithium chloride (LiCl) is an ionic solid used to colour firework displays, like that shown in Figure 12.
(*iv*) Describe how you would carry out a flame test on a sample of LiCl.

Method 1	Method 2	Method 3	**3×3**
use a (clean) platinum wire*	use a damp splint (stick)	prepare a solution of the solid in water and ethanol (propanol)	…3
dip wire in solid	dip splint (stick) in solid	spray solution	…3
hold salt in (over) hot (blue) part of (Bunsen) flame / observe colour of flame	hold salt in (over) hot (blue) part of (Bunsen) flame / observe colour of flame	onto (into) hot (blue) part of flame (Bunsen) / observe colour of flame	…3

*[allow 'inoculating loop', or 'spatula' for 'platinum wire']
[clear labelled diagram acceptable for some or all points]

(*v*) What colour does LiCl give to a flame? **3**
red / crimson …3

(*c*) (*i*) Define the electronegativity of an element. **2×3**
measure of attraction / force or power of attraction / relative attraction (an atom in a molecule has) …3
for a shared pair of electrons / for electrons in a covalent bond …3
['measure of' or 'power of' or 'relative' omitted (–1)]

(*ii*) On a single sheet of graph paper, referring to page 81 of the *Formulae and Tables* booklet, plot the electronegativity values (*y*-axis) *versus* atomic numbers for both the second period elements Li to F, and the first four Group 17 elements F to I. **6, 3**
y-axis labelled electronegativity and x-axis labelled atomic number …6
points plotted appropriately …3

(*iii*) Explain the decrease in electronegativity values shown down Group 17. **3**
additional shell added / increasing atomic radius / more screening or shielding (of nucleus) …3

(*iv*) Use electronegativity values to predict the type of bonding you would expect to occur in the compound NF_3. **2×3**
3.98 – 3.04 / 0.94 …3
polar / polar covalent …3
['covalent' on its own (–1)]

QUESTION 9

Vinegar is a solution of ethanoic acid (CH_3COOH) in water. To determine the concentration of ethanoic acid in a sample of vinegar, 25.0 cm^3 of the vinegar was diluted to exactly 250 cm^3 and then the diluted vinegar was titrated with a standard solution of potassium hydroxide.
The equation for the titration reaction is:

$$CH_3COOH + KOH \rightarrow CH_3COOK + H_2O$$

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

(a solution of) known concentration …6

(*ii*) Name the piece of apparatus shown in Figure 13. **3**

volumetric flask ...3

(*iii*) Describe how the dilution could have been carried out. **3×3**

(25 cm^3) pipette used (to add vinegar to volumetric flask) /
pipette (first) rinsed with deionised or distilled water and (then) vinegar or soln to be measured out /
pipette filler used to fill (pipette) to mark (with vinegar) /
(volumetric) flask rinsed with deionised or distilled water /
deionised or distilled water added (to flask) until near mark /
pipette or dropper use to add last few drops of water /
until bottom of meniscus is on mark /
(flask) stoppered and inverted several times any three in appropriate order …3×3

(*b*) Describe the correct procedure
(*i*) for rinsing a burette, for use in this titration, and **5×3**

rinse with deionised or distilled water …3
rinse with acid or (diluted) vinegar/ rinse with solution it is to deliver or hold …3
['rinse with water' (–1)] [order of rinsing solutions reversed, allow …3 max]

(*ii*) then filling it with the diluted vinegar.

use funnel /
fill above (zero) mark /
open tap to fill part below tap /
(remove funnel and) adjust (approximately) to zero /
use dropper to bring to mark /
bottom of meniscus on (zero) mark /
no bubbles /
clamped vertically any three in appropriate order …3×3

(*c*) (*i*) Name a suitable indicator for use in this titration. **3**

phenolphthalein …3

(*ii*) What colour change would be observed at the end point of the titration? **2×3**

pink ...3
to colourless ...3
[if colours are reversed, allow …3 max]

(*iii*) Explain why it is advisable to use no more than 1 to 2 drops of indicator in a titration. **3**

indicators are weak acids or weak bases / would interfere with or affect result or accuracy or pH of reaction mixture …3

(*iv*) Calculate the molarity of the potassium hydroxide solution that contained 3.36 g of KOH per litre. **4, 2**

M_r = 56

$\frac{3.36}{56}$ = 0.06 (moles per litre) / 0.06 (M) first correct …4, second…2

On average, 18.65 cm^3 of the diluted vinegar was required to neutralise 25.0 cm^3 of this KOH solution. Calculate the concentration of CH_3COOH

(*v*) in the diluted vinegar in moles per litre, **4, 2**

$\frac{V_1 \times M_1}{n_1} = \frac{V_2 \times M_2}{n_2}$ / (volume 1 × molarity 1 × proticity 2) = (volume 2 × molarity 2 × proticity 1) /

$\frac{18.65 \times M_1}{1} = \frac{25.0 \times 0.06}{1}$ / 18.65 × M_1 × 1 = 25.0 × 0.06 × 1 …4

(M_2) = 0.080 (M) …2

or or

(moles of KOH used in 25.0 cm^3 =) $\frac{25 \times 0.06}{1000}$ = 0.0015 (mole) / 0.015 ÷ 10 = 0.0015 mole …4

($\frac{0.0015 \times 1000}{18.65}$) = 0.080 (mole l^{-1}) CH_3COOH …2

(*vi*) in the original vinegar in moles per litre, **3**

0.080 × 10 = 0.80 (M) …3

(*vii*) in the original vinegar in grams per litre. **4, 2**

M_r = 60 …4

60 × 0.80 = 48 (g per litre) …2

QUESTION 10

(*a*) Define

(*i*) oxidation, **6**

loss of electrons …6

(*ii*) reduction, in terms of electron transfer. **6**

gain of electrons …6

(*iii*) Is each of the following two reactions a redox reaction?

$2Na_{(s)} + Cl_{2\,(g)} \rightarrow 2NaCl_{(s)}$ **3**

yes …3

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$ **3**

no …3

Justify your answers. **2×3**

- sodium loses an electron or electrons and chlorine gains it or them / an electron is transferred from a sodium to a chlorine …3
- substances dissociated into ions before and after / no transfer of electrons / no loss and gain of electrons …3

Photochromic glass, containing Ag^+ and Cu^+ ions, darkens when exposed to the ultraviolet radiation in sunlight.
The following reversible redox reaction occurs in the photochromic glass. The glass darkens as clusters of silver atoms are formed.
$Ag^+ + Cu^+ \rightleftharpoons Ag + Cu^{2+}$

(*iv*) In bright sunlight which species is oxidised? **3**

Cu^+ / copper(I) …3

(*v*) When a person wearing the photochromic glasses moves indoors on a sunny day, which species acts as the reducing agent causing the dark colour to fade? **3**

Ag / silver …3

(*b*) Hydrogen produced by the electrolysis of water is described as 'green hydrogen' if renewable electricity is used, e.g. electricity generated from solar energy. Figure 15 shows an apparatus used to electrolyse acidified water, where the power supply is a solar panel.

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

using electricity …3

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

(*ii*) Why were a few drops of acid added to the water before switching on the circuit? **6**

pure water does not conduct electricity / to make the water more conducting …6

(*iii*) State Faraday's first law of electrolysis. **2, 1**

[1]mass of a substance liberated (at an electrode) is proportional to // [2]mass or $m \propto$ // [3]m = …2

[1]the charge that passes // [2]Q // [3]ZIt …1

[allow 'quantity' or 'amount' or 'number of moles' instead of mass]

The balanced equation for the cathode reaction is:

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2\,(g)} + 2OH^-_{(aq)}$$

(*iv*) What charge passed in the circuit when a current of 0.75 A flowed in 10 minutes? **2×3**

$Q = It$ / Q = 0.75 × 10 × 60 …3

($\Rightarrow Q$ =) 450 C …3

[no unit or incorrect unit (–1)]

(*v*) What volume of hydrogen, measured at s.t.p., was collected in the 10 minutes? **2×3**

[1](450 ÷ 96485.3383 =) 4.66×10^{-3} (moles electrons) //

[2](450 ÷ 1.6×10^{-19} =) 2.8125×10^{21} electrons …3

[1](22,400 × (4.66×10^{-3} ÷ 2) = 22,400 × 2.33×10^{-3}) = 52.2 (cm^3) //

[2](22,400 × ((2.8125×10^{21} ÷ 6.022×10^{23}) ÷ 2) = 52.2 (cm^3) …3

(*vi*) What volume of oxygen gas, also measured at s.t.p., was collected at the same time? **3**

52.2 ÷ 2 = 26.1 (cm^3) …3

(*vii*) At which electrode, X or Y, did oxidation occur? **6**

X …6

QUESTION 11

Study the reaction scheme shown in Figure 16 below and answer the questions that follow.

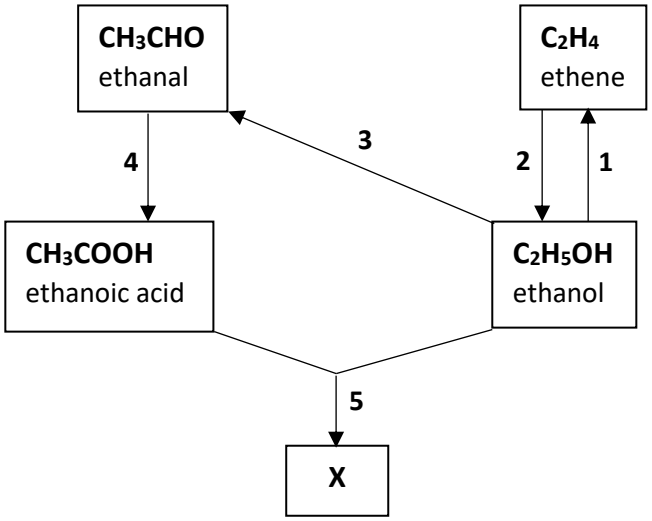


Figure 16

(*a*) (*i*) Ethene is a <u>hydrocarbon</u>.

Explain the underlined term. **<u>6</u>**

compound of hydrogen and carbon only …6

['only' omitted …3]

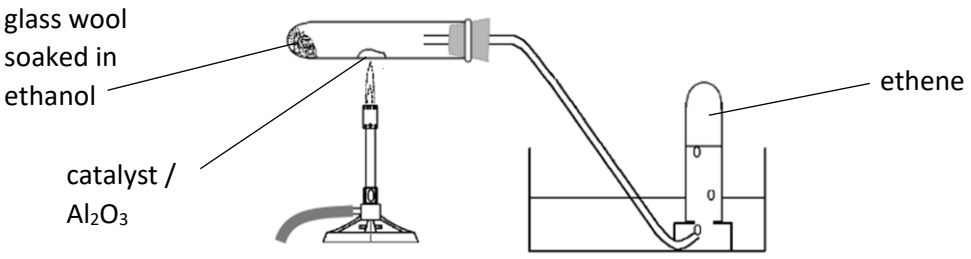
(*ii*) Describe with the aid of a labelled diagram how ethene is prepared from ethanol by reaction 1 and collected over water in the laboratory. **<u>4×3</u>**

horizontal (or slanting), stoppered test tube with delivery tube shown …3

collection over water shown …3

heat applied under alumina …3

reactants labelled …3



[no diagram (−1)] [(−1) for each label or essential feature incorrect or omitted]

(*iii*) Write a balanced equation for reaction 1. **<u>2, 1</u>**

$^1C_2H_5OH \rightarrow$ // $^2C_2H_5OH + Al_2O_3 \rightarrow$ …2

$^1C_2H_4 + H_2O$ // $^2C_2H_4 + Al(OH)_3$ …1

[not balanced (–1)]

(*iv*) How could a test-tube of ethene be tested for unsaturation? **<u>3×3</u>**

^{1}mix with bromine solution // ^{2}mix with (weak) acidified potassium manganate solution …3

^{1}red or yellow or orange or red-brown or brown to // ^{2}pink or purple to …3

^{3}colourless or decolourises …3

(*b*) (*i*) Identify the substance that undergoes an addition reaction in the scheme *and* the inorganic substance added to it in this reaction. **2×3**

ethene / C_2H_4 …3

water / H_2O …3

(*ii*) Identify two oxidation reactions in the scheme *and* name a suitable oxidising reagent for these reactions. **6, 3, 3**

3 / ethanol to ethanal

4 / ethanal to ethanoic acid

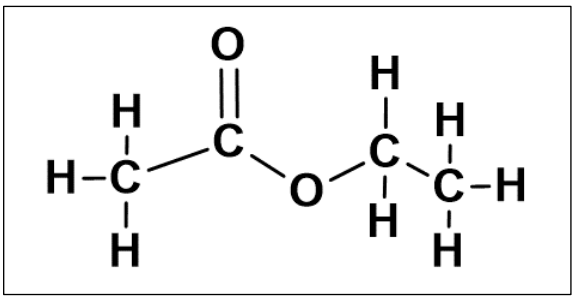
acidified potassium permanganate / acidified sodium or potassium chromate or sodium or potassium dichromate first correct …6, second …3, third …3

[no 'acidified' (−1)]

(*iii*) Give the name of ester X. **6**

ethyl ethanoate …6

(*iv*) Draw a diagram to show all of the atoms and all of the bonds in a molecule of X. **6**



…6

Explain why, in the scheme,

(*v*) the compound with the lowest boiling point is ethene, **3**

ethene is (the only) gas / lightest or smallest molecules / smallest (relative) molecular mass / non-polar / weak intermolecular forces / van der Waals forces / London or dispersion forces …3

(*vi*) the compound with the highest boiling point is ethanoic acid. **3**

strongest intermolecular forces / H-bonding / forms dimers / greatest (relative) molecular mass …3

QUESTION 12

Answer any three of parts (a), (b), (c), (d). Each part carries 22 marks.

Question 12 (*a*)

Antimony (Sb) is an element used in the electronics industry. Antimony is isolated from its ore, stibnite (Sb_2S_3), in the following reactions. Assume both reactions go to completion.

$$2Sb_2S_{3\,(s)} + 9O_{2\,(g)} \rightarrow 2Sb_2O_{3\,(s)} + 6SO_{2\,(g)}$$

$$Sb_2O_{3\,(s)} + 3CO_{(g)} \rightarrow 2Sb_{(s)} + 3CO_{2\,(g)}$$

In the first reaction 12.0 moles of sulfur dioxide were produced from a certain mass of stibnite. Then all the Sb_2O_3 formed reacted with CO to give antimony.

(*i*) How many sulfur (S) atoms were removed from the stibnite to form 12.0 moles of SO_2? **2×2**

$12 \times 6 \times 10^{23}$ …2

$= 7.2 \times 10^{24}$ (atoms sulfur) …2

(*ii*) What mass of antimony was extracted from its ore in these reactions? **3×3**

(Sb_2O_3 : antimony = 1 : 2 $\Rightarrow$) 8 moles (antimony) …3

$A_r = 122$ …3

$(8 \times 122) = 976$ g (Sb) …3

(*iii*) How many litres of CO, measured at s.t.p., were used up in the second reaction? **2×3**

(antimony : CO = 2 : 3 $\Rightarrow$) 12 moles (carbon monoxide) …3

$(12 \times 22.4 =)$ 268.8 (litres CO) …3

(*iv*) What is the valency of antimony in Sb_2O_3? **3**

3 …3

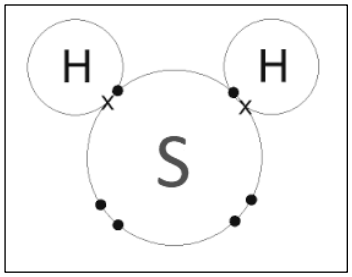
Question 12 (*b*)

(*i*) Draw a (dot and cross) diagram to show the arrangement of the valence electrons in a molecule of hydrogen sulfide (H_2S). **4, 3**

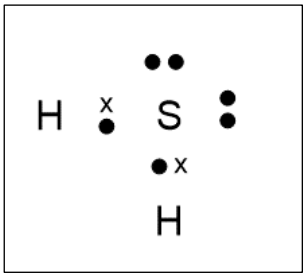
2 lone pairs or 4 non-bonding electrons in S valence shell

2 bond pairs first correct answer …4, second …3

[shape not required in diagram]



or



(*ii*) State the shape of a H_2S molecule. **3**

v / bent / angular …3

(*iii*) Does a molecule of gaseous H_2S have an overall dipole moment? **3**

yes …3

XH_2 is a compound of hydrogen and another element X. Its molecules do not have an overall dipole moment. X is in the second period of the periodic table.

(*iv*) Identify X. **3**

beryllium / Be …3

State

(*v*) the shape of, **3**

linear …3

(*vi*) the bond angle in, a molecule of XH_2. **3**

180° …3

Question 12 (*c*)

(*i*) State Hess's law. **2×3**

[1]heat change for a reaction // [2]algebraic sum of heat changes of the stages equal to …3

[1]independent of path followed / depends only on initial and final states // [2]heat change for reaction taking place in one step …3

Consider the following heats of reaction.

$\mathbf{4B_{(s)} + 3O_{2\,(g)} \rightarrow 2B_2O_{3\,(s)}}$	$\mathbf{\Delta H}$	**–2,547.0 kJ**
$\mathbf{2H_2O_{(l)} \rightarrow 2H_{2\,(g)} + O_{2\,(g)}}$	$\mathbf{\Delta H}$	**571.6 kJ**
$\mathbf{B_2O_{3\,(s)} + 3H_2O_{(l)} \rightarrow B_2H_{6\,(g)} + 3O_{2\,(g)}}$	$\mathbf{\Delta H}$	**2167.3 kJ**

(*ii*) Use Hess's law and the information given above to calculate the heat change for the following reaction.

$\mathbf{2B_{(s)} + 3H_{2\,(g)} \rightarrow B_2H_{6\,(g)}}$ **4×3**

$2B_{(s)} + 1½O_{2\,(g)} \rightarrow B_2O_{3\,(s)}$	ΔH =	–1273.5 kJ	…3
$3H_{2\,(g)} + 1½O_{2\,(g)} \rightarrow 3H_2O_{(l)}$	ΔH =	–857.4 kJ	…3
$B_2O_{3\,(s)} + 3H_2O_{(l)} \rightarrow B_2H_{6\,(g)} + 3O_{2\,(g)}$	ΔH =	2167.3 kJ	…3
$2B_{(s)} + 3H_{2\,(g)} \rightarrow B_2H_{6\,(g)}$	ΔH =	36.4 kJ	…3

Use the heats of reaction given above to calculate

(*iii*) the heat of combustion of boron (B), **2**

(–2547.0 ÷ 4=) –636.75 (kJ mol^{-1}) …2

(*iv*) the heat of formation of water. **2**

(–571.6 ÷ 2=) –285.8 (kJ mol^{-1}) …2

Question 12 (*d*)

Define, according to Brønsted-Lowry theory, **6, 3**

(*i*) an acid,

proton donor or H^+ donor

(*ii*) a base.

proton acceptor or H^+ acceptor first correct …6, second …3

(*iii*) Distinguish between a strong acid and a weak acid. **6 or 2×3**

the greater the tendency of an acid to donate protons (the more the acid tends to dissociate into ions) the stronger it is / the smaller the tendency of an acid to donate protons (the less the acid tends to dissociate into ions) the weaker it is …6

or or

strong acid:

is a good proton (H^+) donor / has a weak conjugate base / fully dissociated /
has large (complete) degree of dissociation into ions / K_a value large …3

weak acid:

is a poor proton (H^+) donor / has a strong conjugate base /
dissociated into ions to small extent / slightly or partially dissociated / K_a value small …3

(*iv*) Define pOH. **2**

$pOH = -\log[OH^-]$ …2

(*v*) What is the relationship between pH and pOH? **2**

$pH + pOH = 14$ …2

The pH of a HCl solution is 2.0 according to a pH meter as shown in Figure 17.

(*vi*) Calculate the concentration of the HCl solution in moles per litre. **2, 1**

([HCl] =) inverse log –pH / ([HCl] =) inverse log –2.0 / ([HCl] =) $10^{-2.0}$ / 2 = $-\log_{10}[H^+]$ …2

($\Rightarrow$ [HCl] =) 0.01 (M) …1