Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2021

Marking Scheme

Physics and Chemistry

Ordinary Level

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

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

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

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

Future Marking Schemes

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

Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION

PHYSICS AND CHEMISTRY – ORDINARY LEVEL

General Guidelines

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

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

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

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

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

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

6. Where indicated, 1 mark is deducted for incorrect/ no units.

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

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

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

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

Coimisiún na Scrúduithe Stáit

Marcanna Breise as ucht freagairt trí Ghaeilge

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

Tábla 330 @ 10%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 330 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.
Bain úsáid as an ngnáthráta i gcás 247 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

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

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

Question 1
Any eleven parts **11×6**

(*a*) What is meant by *kinetic energy*? **4, 2 or 6**
energy due to // energy of a …2
motion or movement // moving body …4
or
$\frac{1}{2}mv^2$ …6

(*b*) State one of Newton's laws of motion. **2×3**
First law: object will remain at a constant velocity (or at rest) …3
unless acted upon by a force …3

or

Second law: rate of change of momentum is proportional …3
to applied force and in same direction …3

or

Third law: for every action there is …3
an equal and opposite reaction …3

(*c*) A police officer using a self-balancing scooter as shown in Figure 1 increased her velocity from 2 m s^{-1} to 5 m s^{-1} in 6 s. What was her acceleration? **2×3**
$a = \frac{v-u}{t}$ / $v = u + at$ …3
($a = \frac{5-2}{6}$ =) 0.5 (m s^{-2}) …3

(*d*) Define work. **2×3**
force / *F* × …3
moves (an object certain) through a distance / displaces (object) // *s* or *d* …3
[Accept energy …6][Joule …3]

(*e*) Copy and complete the following statement of Boyle's law: "At constant temperature the ……. of a fixed mass of gas is inversely proportional to its ……." **2×3**
pressure // volume …3
volume // pressure ...3
[*PV* is constant or $P \propto 1/V$ …3]

(*f*) A chocolate sweet melts at 310 K. What is this temperature on the Celsius scale? **6**
310 – 273.(15) = 36.85 – 37 (°C) ...6
[reference to 273.(15) …3]

(*g*) What term describes the gas which obeys the gas laws at all temperatures and pressures? **6**
ideal or perfect …6

(*h*) Compare the thickness of glass at the centre of a magnifying glass with the glass at its edge. **6**
thicker at centre / thinner at edge …6

(*i*) Figure 2 shows a set of wavefronts approaching a narrow opening.
Copy the diagram to show the path of the wavefronts after passing through the opening. **6**

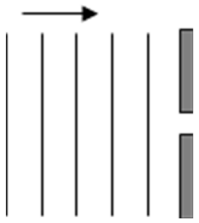


Figure 2

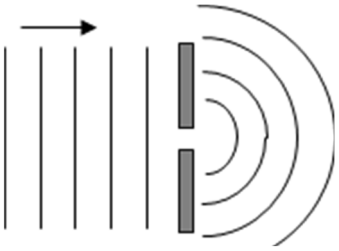


Figure 2 completed

diffraction shown for at least two wavefronts …6
[diagram copied and attempt to draw wavefront…3]

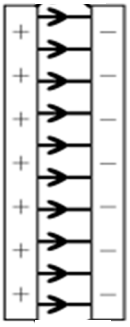
(*j*) Name a phenomenon which occurs due to light travelling at different speeds in different media. **6**
refraction / dispersion / total internal reflection / etc

(*k*) How would you detect a magnetic field? **6**
compass / iron filings / (using another) magnet / magnetometer / Hall effect **…6**

(*l*) What is the photoelectric effect? **2×3**
release of electrons from (surface of) a metal …3
illuminated by electromagnetic radiation or light (above a certain frequency) …3

(*m*) Figure 3 shows a fuse from a three-pin plug.
On which effect of an electric current is its operation based? **6**
heating ...6

(*n*) Sketch a diagram to show the electric field pattern between a pair of parallel plates of a charged parallel-plate capacitor. **2×3**



parallel field lines between plates …3
direction of field lines …3

(*o*) Figure 4 shows two 10 µF capacitors connected in parallel.
Calculate the effective capacitance of the combination. **2×3**
$C_1 + C_2 = C$ …3
(C =) 10 + 10 = 20 (µF) …3
[Allow 0.2 or 5 (µF) ...3]

(*p*) Calculate the number of units (kW h) used by a 3 kW electric kettle in 6 minutes. **2×3**
6 ÷ 60 = 1/10 (tenth of an hour) = 0.1 (hours) …3
3 × 0.1 = 0.3 (units) …3
[3 × 6 = 18 …3]

(*q*) Name the type of nuclear radiation which exists as electromagnetic radiation. **6**
gamma or γ (radiation) …6

(*r*) What happens to nuclei during nuclear fission? **6**
break up / spilt into fragments / split into two …6
[Allow neutrons released …3]

Question 2

(*a*) State the law of conservation of energy. **4, 2**

energy cannot be created or destroyed // $mgh + \frac{1}{2}mv^2$ // $\Delta E_p + \Delta E_k$ …4

but can be converted from one form into another // = constant // = 0 …2

Give the SI unit of (i) *mass*, **6**

kilogram / kg …6

(ii) *weight*. **6**

newton / N …6

[kg m s^{-2} acceptable …6][kg/m s^{-2} …5]

(*b*) Learning to juggle is a fun activity.

A juggling ball of mass 011 kg was tossed vertically upwards and reached its maximum height of 2.0 m above the initial position after time *t*.

Calculate

(i) the weight of the juggling ball **3×3**

(W =) mg …3

(W =) 0.11 × 9.8 …3

(W =) 1.078 N / 1.1 N …3

[no unit or incorrect unit (–1)]

(ii) the potential energy gained by the ball when it reached its maximum height **3×3**

(E =) mgh / (E =) Wh …3

mg = 0.11 × 9.8 = 1.078 ….3

(E =) 0.11 × 9.8 × 2.0 = 2.156 J / (E =) 1.078 × 2.0 = 2.156 J – 2.2 J …3

[no unit or incorrect unit (–1)]

(iii) the time taken for the ball to fall from rest at its maximum height back to its initial position.

$s = ut + \frac{1}{2}at^2$ / $s = \frac{1}{2}at^2$ / $2.0 = \frac{1}{2} \times 9.8 \times t^2$

$\Rightarrow$ (t =) 0.64 s

[no unit or incorrect unit (–1)]

[acceleration due to gravity, g = 9.8 m s^{-2}]

The juggler then threw the ball from one hand upwards at an angle to the vertical and caught it with the other hand as shown in Figure 5.

(iv) What was the ball's *vertical* velocity when it was at its maximum height?

zero

(v) Why did its *horizontal* velocity stay constant as it moved from the throwing hand to the catching hand?

no force (horizontally) / juggler gives it only an initial horizontal push / only force is vertical or gravity

first part of (iii), (iv) and (v) correct …6, second part …2, last part …1

(*c*) Describe, with the aid of a labelled diagram, an experiment to measure the acceleration due to gravity, *g*. **2×3, 6, 3**

Arrangement of apparatus shown in diagram

pendulum: suspended bob, string //

freefall apparatus: ball, electromagnet, trapdoor or stop/start timing circuit //

freely falling object: timer, defined drop

any two…2×3

[no diagram allow …3 max]

Procedure
pendulum: measure time for bob to complete one oscillation / measure length of string //
freefall apparatus: measure time for fall from electromagnet to trapdoor / measure drop //
freely falling object: measure time for object to fall from rest / through measured drop

any one…6

Measurements / Data handing

pendulum: find *g* from formula $T = 2\pi\sqrt{\frac{l}{g}}$ or $T^2 = 4\pi^2\frac{l}{g}$ or graph of *T* versus $\sqrt{l}$ or T^2 versus *l* and find *g* from slope of graph //
free fall apparatus or freely falling object: find *g* using formula $s = \frac{1}{2}gt^2$ or graph *s* versus t^2 and find *g* from slope of graph

any one…3

Give one precaution to ensure an accurate result. **6**
pendulum: average time for several oscillations, repeat (for different lengths of string), use long string, measure length to centre of bob, clamp with split cork, etc /
free fall apparatus: minimum time for several falls of same length, repeat (for different lengths of fall), use long fall, measure drop from bottom of ball to top of trapdoor, paper between ball and electromagnet, etc /
freely falling object: repeat to get minimum time for several falls of same length, repeat (with different defined drop lengths), use electronic start/stop and not manual start stop system, etc /
repeat (experiment) and average (results) any one…6

[Accept average time for several falls …3]

Question 3

(*a*) State the laws of reflection of light. **9, 3**

the angle of incidence is equal to the angle of reflection / $i = r$
[refraction instead of reflection (–3)] [sines mentioned (–3)]
[allow object distance is equal to image distance …6]

and

the incident ray or beam, the reflected ray or beam and the normal (all) lie in the same plane
[normal omitted (–1)][refraction instead of reflection (–1)]

first correct …9, second correct…3

(*b*) The outer surface of the human eye is shaped like a convex mirror. Figure 6 shows the reflection of a light source when a person's eye acts as a convex mirror.
Give two properties of all images formed by convex mirrors. **2×6**

diminished / upright / virtual / always between focus or F and pole or P any two….2×6

(*c*) What is the distance *between* a pencil and its image when the pencil is held upright 10 cm in front of a plane mirror? **6**

20 cm …6
[no unit or incorrect unit (–1)]

Give the difference between the properties of the images formed by a plane mirror and those formed by a convex mirror. **6**

(images in plane mirror) same size (as object) or not diminished / magnification = 1 in plane mirror / magnification < 1 in convex mirror …6
[Accept image distance (in plane mirror) and object distance always equal.]

(*d*) Figure 7 shows a pin placed in front of a concave mirror.
Copy and complete the diagram to show the paths of the reflected rays converging at the head of the pin's image. **3, 6, 3**

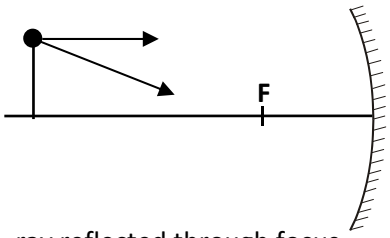


Figure 6

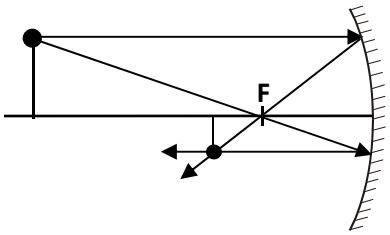


Figure 6 completed

ray reflected through focus
ray reflected parallel to principal axis

copy diagram …3, first ray drawn correctly …6, second ray drawn correctly …3

Where, in terms of F, must the pin be placed to produce a magnified upright image in the concave mirror? **6**

inside focus / less than 5 cm from mirror …6

(*e*) Give two uses for curved mirrors. **2×6**

produce a magnified image / produce a diminished image / produce an inverted image / in dentistry / for shaving / for make-up application / reflector in lamp / security (mirror) / wide-field of view or blind exit mirror, etc any two….2×6
[distinct uses for lens or plane mirror….2×3]

Question 4

(*a*) Molecules in a gas can be modelled using the kinetic theory.

Give two assumptions of the kinetic theory of gases. **2×6**

large number of particles or molecules / rapid motion / random motion / straight line motion / collisions occur between particles or molecules / collisions occur with walls of container / collisions elastic or involve neither loss nor gain of energy / negligible volume occupied by particles or molecules / negligible duration of collisions / no forces between particles except during collisions, etc any two…2×6

How does Brownian motion provide evidence for the kinetic theory? **6**

shows how molecules move / motion of molecules or particles (of matter) …6

Figure 8 shows a table tennis ball which was dented during use.

Explain why the pressure of the air inside the table tennis ball changed when it was dented. **6**

smaller volume / more collisions with walls / pressure and volume inversely proportional …6

[Allow pressure increased …6]

The table tennis ball was restored to its original shape by submerging it in warm water.

Explain why heating the dented ball changed the motion of the molecules inside it. **9**

heat is a form of energy / (molecules) more energetic or have more kinetic energy / (molecules move) faster / (exert) more pressure / collide more often …9

(*b*) Figure 9 shows a liquid-in-glass thermometer commonly used in the laboratory.

Name a liquid often used for this purpose *and* give a reason for its suitability. **2×6**

alcohol // mercury // kerosene, etc …6

alcohol: wide or suitable temperature range / non-toxic / easily dyed / reads low temperatures / sensitive / accurate //

mercury: easy to see / suitable or wide temperature range / reads high temperatures / accurate or sensitive (enough for most uses) //

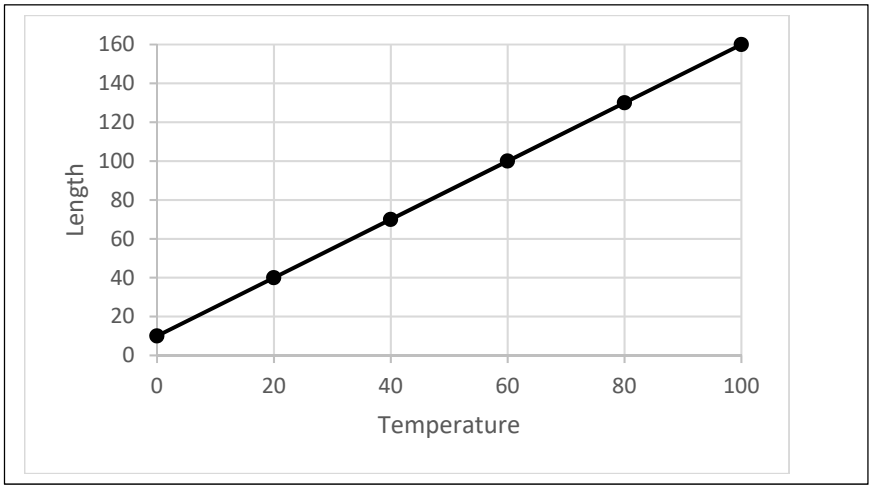
kerosene, etc: easily dyed / suitable temperature range / non-toxic …6

The length of the liquid thread in a thermometer was measured at different temperatures and the following data were recorded:

Length (mm)	**10**	**40**	**70**	**100**	**130**	**160**
Temperature (°C)	**0**	**20**	**40**	**60**	**80**	**100**

Draw a graph (on graph paper) showing length (*y*-axis) against temperature (*x*-axis) **5×3**
x-axis labelled temperature or °C …3
y-axis labelled length or L or mm …3
six points plotted correctly …3
points joined by a line …3
of good fit …3
[Allow 12 (max) if graph paper not used.][No penalty if axes reversed].

Use your graph to estimate the length of the liquid thread at 50 °C. **6**
85 ± 2 mm …6
[no unit or incorrect unit (–1)]



Question 5

(*a*) Electric current is the flow of electrical charge.

Name the S.I. unit of current. **6**

ampere / amp …6

What are the two requirements to enable an electric current to flow? **2×6**

(switch to) complete circuit / conducting or metallic pathway …6

power supply / potential difference / battery …6

(*b*) The table below shows the times taken for a charge of 6 coulombs to pass a point in an electrical circuit when different currents flow.

Current (A)	6.0	3.0	2.0	1.5	0.5
Time (s)	1	2	3	4	12

Draw a graph (on graph paper) of current (*y*-axis) against time (*x*-axis) **5×3**

x-axis labelled time or *t* or *s* …3

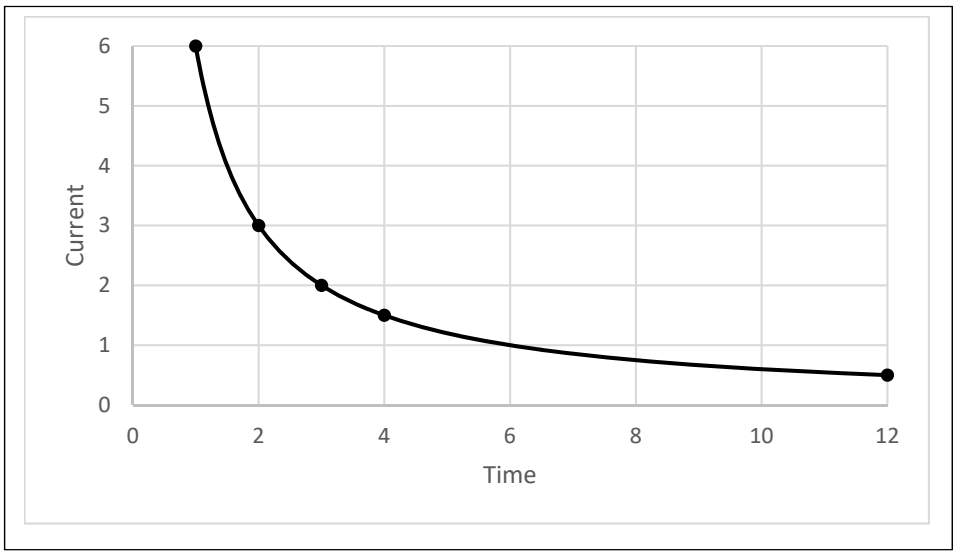
y-axis labelled current or *I* or A or amp or ampere …3

five points plotted correctly …3

points joined by a curve …3

of good fit …3

[Allow 12 (max) if graph paper not used.][No penalty if axes reversed].



Estimate from your graph the time taken for 6 C to pass when the current in the circuit is 0.75 A. **6**

10 ± 1 s …6

[no unit or incorrect unit (–1)]

(*c*) Figure 10 shows two circuits, X and Y. Each circuit has two 5 Ω resistors connected to a 9 V battery. What is the value of the single resistor that could replace the combination of resistors in

(i) circuit X, **6, 3**

$R = R_1 + R_2$ / $R = 5 + 5$ …6

($\Rightarrow R =$) 10 (Ω) …3

[parallel here instead of series …6 max]

(ii) circuit Y? **2×3**

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} / \frac{1}{R} = \frac{1}{5} + \frac{1}{5} / \frac{1}{R} = \frac{2}{5}$ …3

($\Rightarrow R =$) 2.5 (Ω) …3

[series here instead of parallel …3 max]

(iii) Calculate the current flowing in circuit X. **6, 3**

$V = IR$ / $I = \frac{V}{R}$ …6

($\Rightarrow I =$) 9.0 ÷ 10 = 0.9 A / ($\Rightarrow I =$) 4.5 ÷ 5 = 0.9 A …3

[no unit or incorrect unit (–1)]

(iv) What is the voltage (potential difference) across the resistor marked R in circuit Y? **3**

9 V …3

[no unit or incorrect unit (–1)]

Question 6
Answer any two parts. **2×33**

(*a*) State the *principle of conservation of momentum*. **3×3**
when no external force acts or in a closed system …3
momentum before equals // (total) momentum remains or is // $m_1u_1 + m_2u_2$ …3
momentum after // constant // $m_1v_1 + m_2v_2$ or $(m_1 + m_2)v$ …3

[the rate of change of momentum is proportional to the applied force, allow…3]
[principle of conservation of energy, allow…3]

Figure 11 shows two shopping trolleys each of mass 30 kg on a smooth horizontal floor.

Trolley A moving at 2.5 m s^{-1} collides with trolley B which is at rest.
After the collision both trolleys move together in the same direction.

Calculate
(i) the initial momentum of trolley A **2×3**
mv or *mu* / 30 × 2.5 …3
(*mv* or *mu* =) 75 kg m s^{-1} (to the right) …3
[no unit or incorrect unit (–1)]

(ii) the velocity of the trolleys moving together after the collision. **3×3**
$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ / 75 + (30 × 0) = $(m_1 + m_2)v$ / 75 = 60*v* …3
$v = \frac{75}{60}$ …3
(*v* =) 1.25 m s^{-1} (to the right) …3
[no unit or incorrect unit (–1)]*

If trolley A was loaded with groceries giving it a total mass of 45 kg, what velocity would give it the same initial momentum as in part (i)? **3×3**
(*mv* or *mu* =) 75 (kg m s^{-1}) …3
75 ÷ 45 …3
(*u* or *v* =) = 1.67 m s^{-1} (to the right) …3
[no unit or incorrect unit (–1)]*
*penalise once only

(*b*) Uranium has several isotopes, all of which are radioactive, and each isotope has a unique half-life. Explain the underlined terms. **4×3**

radioactive:

unstable (nucleus) / nucleus decays …3

emitting radiation or emitting alpha, beta and gamma (radiation) …3

half-life:

time taken …3

for half a (radioactive) sample to decay / for activity to decrease by half by 50% …3

or

ln2/ λ …6

Uranium-234 has a half-life of 0.25 million years and it decays to thorium-230 by emitting an alpha-particle

What fraction of a given sample of uranium-234 would remain after 0.75 million years? **2×3**

3 half-lives …3

(½ → ¼ →) 1/8 …3

In terms of subatomic particles, what is the composition of

(i) an alpha-particle

two protons and two neutrons // helium (nucleus) // He_2^4

(ii) a beta-particle? **6, 3**

electron or positron

first correct ..6, second correct….3

How can a stream of moving alpha-particles be deflected? **6**

electrical field / magnetic field …6

(*c*) Figure 12 shows a waveform.
Copy the diagram and clearly show (i) the amplitude, (ii) the wavelength, of the waveform. **3,6,3**

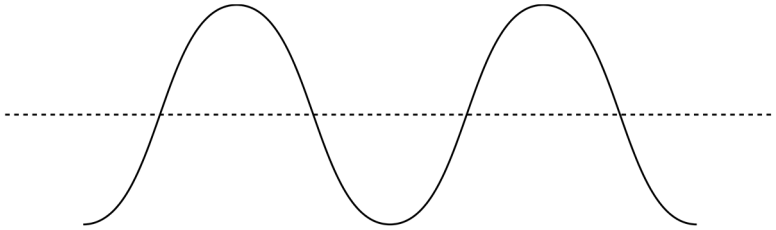


Figure 11

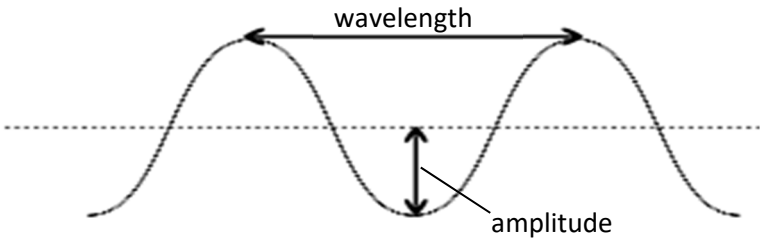


Figure 11 completed

wavelength / λ
amplitude / A
[Diagram copied 3, first correct 6, second correct 3]

The wavelength of monochromatic light can be found using a pair of narrow slits.
Explain the underlined term. **6**
all one or same frequency or colour or wavelength or photon energy …6

Give an example of a monochromatic light source. **3**
sodium lamp / laser, etc …3

State two measurements which are recorded during an experiment to find the wavelength of monochromatic light with a pair of narrow slits. **2×6**
distance between slits and screen / distance between images on screen / angular separation of images …6
separation between slits …6

(*d*) What is *electromagnetic induction*? **2×3**

production of current or voltage or emf (in a conductor or coil) …3

from a (nearby changing) magnetic field …3

Figure 13 shows a dynamo torch which operates on the principle of electromagnetic induction.

Identify another device based on the principle of electromagnetic induction. **6**

alternator, generator, transformer, induction hob or cooker, etc any one…6

Figure 14 shows a galvanometer connected to the ends of a coil of wire near a rotating bar magnet.

As the magnet completes one rotation, the needle in the galvanometer deflects first to the right and then to the left.

What does a galvanometer detect? **6**

current …6

Why does the needle in the galvanometer show no deflection if the magnet remains stationary? **6**

no induction or emf or current (unless there is movement) / induction requires movement /

no movement between coil and magnetic field or magnet …6

Is this arrangement a source of *a.c.* or *d.c.* as the magnet continuously rotates? **6**

a.c. …6

Give a reason for your answer. **3**

(induced) current reverses direction (when magnet is moving towards and then away from coil) …3

Question 7

Any eleven parts **11×6**

(*a*) What type of atomic orbital is shown in Figure 15? **6**

p …6

[Allow dumbbell …3]

(*b*) Give one property of a transition element. **6**

metallic / variable valency / coloured compounds / good catalysts / (react by) losing electrons …6

(*c*) How many (i) protons, (ii) neutrons are there in $^{11}_{5}\mathrm{B}$? **4, 2**

(i) 5 (protons)

(ii) 6 (neutrons)

first correct…4, second correct...2

(*d*) Select the two Group 2 metals from the following:

lithium beryllium sodium magnesium titanium **4, 2**

beryllium

magnesium

first correct…4, second correct...2

(*e*) Red phosphorus is one *allotrope* of the element phosphorus. What are allotropes? **2×3**

different physical forms …3

of same element …3

(*f*) Give the group number of the most stable elements in the Periodic Table. **6**

18 / 0 …6

[Allow 8 or VIII ….6]

(*g*) The element potassium has three naturally occurring isotopes, one of which is radioactive. As a result, bananas are slightly radioactive because they contain potassium. Explain the underlined term. **2×3**

atoms with same atomic number or same number of protons …3

different numbers of neutrons / different mass number …3

(*h*) What type of bond exists *between* the water molecules in ice? **6**

hydrogen (bond) / dipole-dipole (interaction) …6

[Allow intermolecular (force) ….5]

(*i*) Calculate the percentage of calcium by mass in calcium oxide (CaO).

[O = 16; Ca = 40] **4,2**

(M_r = 40 + 16) = 56 ...4

$\frac{40}{56} \times 100 = 71.4\%$ …2

(*j*) Define electronegativity. **2×3**

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

for electrons in a shared pair or in a covalent bond …3

(*k*) The nitrogen gas used to inflate a racing-car tyre like that in Figure 16 has a volume of 168 litres measured at s.t.p. What is the mass of this quantity of N_2 gas?
[N = 14; molar volume at s.t.p. = 22.4 litres] **2×3**
(168 ÷ 22.4 =) 7.5 (moles) …3
(7.5 × 28 =) 210 (g) …3

(*l*) Define the heat of formation of a compound. **2×3**
heat change when one mole of a substance ...3
is formed from its elements in their standard states …3
[one mole omitted (–1); in their standard states (–1)]

(*m*) Hydrochloric acid reacts with magnesium metal to form a salt and hydrogen gas.
Copy, complete and balance the following equation for this reaction:
HCl + Mg → _____ + _____ **4, 2**
$2HCl + Mg \rightarrow MgCl_2 + H_2$
formulae …4
balanced …2
[Where marks above not awarded, $MgCl_2$ or H_2...3]

(*n*) What is a catalyst? **4,2**
changes or increases rate of reaction …4
without being used up …2

(*o*) The electrolysis of acidified water produces two gases.
Identify the gas produced in the larger volume. **6**
Hydrogen / H_2 …6
[Allow H …3] [Allow oxygen / O_2 …3]

(*p*) What two substances are always formed when any hydrocarbon is burned in excess oxygen? **2×3**
carbon dioxide / CO_2 …3
water / H_2O …3

(*q*) Identify one of the organic products of oxidation of ethanol. **6**
ethanal or CH_3CHO / ethanoic acid or CH_3COOH or vinegar ...6

(*r*) Identify the aromatic molecule represented in Figure 17. **6**
phenol / hydroxybenzene / benzenol …6

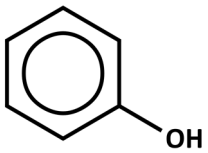


Figure 17

Question 8

Refer to page 79 of the *Formula and Tables* booklet when answering this question.

(*a*) (i) How many electrons are there in a neutral atom of sodium? **6**

11 …6

(ii) Write the electronic configuration (*s*, *p*) of an atom of sodium. **2×3**

$1s^2\ 2s^2$ …3

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

[Allow 2,8, 1 …3]

(*b*) Ions of sodium are present in $NaHCO_3$, the compound found in bread soda.

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

Ions:

charged // charged groups …3

atom(s) // of atoms …3

Compound:

two or more elements …3

joined or bonded (chemically together) …3

(ii) How many protons are there in one Na^+ ion? **6**

11 …6

(iii) Identify one other compound containing sodium ions and give a common use for it. **2×3**

sodium chloride or NaCl // sodium hydroxide or NaOH // sodium carbonate or Na_2CO_3 // etc …3

flavouring, etc // drain or oven cleaner or base (for laboratory work), etc // washing soda, etc // etc …3

(iv) What type of chemical bonding is found in both compounds? **6**

ionic …6

(v) State two characteristic properties of compounds with this type of bonding. **2×3**

solid / hard / brittle / crystalline / high melting point / high boiling point / water soluble / conduct electricity when molten or dissolved (in water) any two…. 2×3

(*c*) Figure 18 represents the structure of sodium metal.

What type of bonding is present within a sample of sodium metal? **6**

metallic …6

Which subatomic particle freely moves throughout the structure? **6**

electron(s) …6

Give two properties characteristic of substances with this type of bonding. **2×3**

solid / crystalline / (usually) hard / often strong / shiny or lustrous / malleable / ductile / conduct electricity / good heat conductors any two…. 2×3

Question 9

(*a*) (i) State the Brønsted-Lowry definition of a base. **2×3**

proton / H^+ …3

acceptor …3

[Allow base produces hydroxide ions or OH^- (in solution) ...5]

(ii) Identify two bases in the following equation.

$H_2SO_4 + NH_3 \rightleftharpoons HSO_4^- + NH_4^+$ **9, 3**

NH_3

HSO_4^-

first correct…9, second correct...3

(iii) Give an example of an acid-base conjugate pair in this reaction. **6, 3**

H_2SO_4 // NH_4^+ …3

and HSO_4^- // and NH_3 …6

[Either acid on its own …3]

(iv) Calculate the pH of a 0.0065 M nitric acid (HNO_3) solution. **2×3**

pH = − log[H^+] ...3

pH = –log[0.0065] = 2.187 – 2.2 ...3

(*b*) Many elements react with oxygen to form oxides and with hydrogen to form hydrides.
Give the formula of

(i) the oxide formed when magnesium reacts with oxygen **6**

MgO …6

(ii) the hydride formed when sulfur reacts with hydrogen. **6**

H_2S …6

Magnesium is oxidised when it reacts with hydrogen to form MgH_2.

(iii) Which element gains electrons in this reaction? **…3**

hydrogen / H / H_2 …3

Sulfur is reduced when it reacts with hydrogen.

(iv) Which element acts as the oxidising agent in this case? **3**

sulfur / S …3

(*c*) Metals corrode when they are oxidised by chemicals in their environment.
List the metals iron, magnesium and silver in order of their ease of oxidation, i.e. in order starting with the metal most easily oxidised. **9**

magnesium, iron, silver / Mg, Fe, Ag …9

[two metals in correct order …3][reversed …6]

Suggest a way, that does not involve a chemical reaction, of preventing corrosion of a metal. **6**

oil / paint or varnish / greasing / coat in plastic …6

[Allow galvanising …6]

Question 10

(*a*) The concentration of a solution of potassium hydroxide (KOH) prepared in a 250 cm^3 volumetric flask was found by titration.

(*a*) This solution was prepared from pellets of KOH and deionised water.

(i) Why was *deionised* water used? **6**

purity / to avoid impurities / tap water contains impurities / ions in tap water could affect result / accuracy of result improved …6

(ii) How would you know that the KOH pellets were fully dissolved? **3**

no solid visible or remaining / no grains or pellets can be felt when stirring / transparent or clear solution formed / pellets disappeared …3

(iii) Name two pieces of personal protective equipment (PPE) that should have been worn during the preparation. **6, 3**

goggles or eye protection / gloves / hair-tie / lab-coat or apron / PPE

first correct…6, second correct…3

(*b*) A 25.0 cm^3 portion of this KOH solution measured into a conical flask, was titrated with a standard solution of hydrochloric acid (HCl) in the presence of an acid-base indicator. Two items of glassware X and Y, used in the titration are shown in Figure 19.

(i) Explain the underlined term. **2×3**

concentration …3

known …3

(ii) Name X and Y. **2×6**

X: burette …6

Y: pipette …6

(iii) Give a precaution when preparing X for use in the titration. **6**

rinse with deionised water and with HCl or solution it will contain /
clamp vertically /
fill part below tap (before zeroing) /
read at eye level /
bottom of meniscus in line with mark, etc …6

(iv) Suggest a suitable acid-base indicator for use in this titration. **6**

methyl orange / phenolphthalein / litmus, etc …6

(v) What is meant by the *end point* of a titration? **3**

sufficient acid or one substance added to just neutralise or react with base or other substance / neutralisation point / (when indicator or solution just) changes colour …3

(*c*) On average, 23.6 cm^3 of 0.18 M HCl were required to neutralise a 25.0 cm^3 portion of the KOH solution from the volumetric flask. The balanced equation for the titration reaction is:

$$HCl + KOH \rightarrow KCl + H_2O$$

(i) Why should the titration be repeated a number of times to get an *average* volume of acid needed to neutralise the KOH? **3**

more accurate / cancels or compensates for experimental errors …3

(ii) Why should the volume of acid added in the *first* titration generally *not* be included when calculating this average? **3**

(first titration is) rough or inaccurate / (first titration) an estimate or approximation / only results within 0.1 cm^3 or in very close agreement are averaged ...3

(iii) Calculate the concentration of the KOH solution in the volumetric flask. **3×3**

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

$\frac{\mathbf{23.6 \times 0.18}}{\mathbf{1}} = \frac{\mathbf{25.0 \times M_2}}{\mathbf{1}}$ ...3

(M_2 =) 0.16992 – 0.17 (mole/l) ...3

[correct formula, incorrect substitution ...6 max]

or

moles of HCl used = $\frac{23.6 \times 0.18}{1000}$ ...3

(moles HCl used) = 0.00428 ...3

0.00428 moles of KOH in 25.0 $cm^3 \Rightarrow \frac{0.00428 \times 1000}{25.0}$ = 0.16992 (moles /L) [0.16992 – 0.17 M] ...3

Question 11

(*a*) Which two elements are found in hydrocarbons? **2×3**

carbon / C …3

hydrogen / H …3

Identify a major source of hydrocarbons. **6**

rotting vegetation, slurry pits, coal, crude oil, etc …6

Butane (C_4H_{10}), propene (C_3H_6) and ethyne (C_2H_2) are members of three different homologous series.

(*b*) Name the three homologous series to which each of these compounds belong. **3×3**

alkanes …3

alkenes …3

alkynes …3

[any order]

Identify the first member of each of these three homologous series. **3×3**

methane …3

ethene …3

ethyne …3

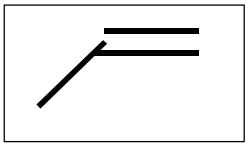
[no need to match]

(*c*) What is an *unsaturated* hydrocarbon? **6**

contains double (or triple) or multiple (carbon-carbon) bond /

can add hydrogen to give only single (carbon-carbon) bond …6

Sketch the structural formula of propene. **6**



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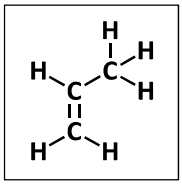


…6

Hs need not be shown explicitly

How could you verify that propene is an unsaturated hydrocarbon? **6, 2, 1**

bromine solution or bromine water or bromine in named solvent // acidified (dilute) $KMnO_4$ (solution) /

bring ethyne and bromine (solution) together // bring ethyne and $KMnO_4$ (solution) together /

red or brown or orange or yellow colour initially / pink or purple colour initially /

becomes colourless (is a positive test result)

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

(*d*) Hydrogen adds to propene according to the following balanced equation:

$$C_3H_6 + H_2 \rightarrow C_3H_8 \quad \Delta H = -124.7 \text{ kJ mol}^{-1}$$

Is this addition reaction *exothermic* or *endothermic*? **3**

exothermic …3

Give a reason for your answer. **3**

ΔH negative / heat given out …3

Calculate the overall quantity of energy involved when 5 moles of C_3H_6 react fully. **2×3**

5 × 124.7 = …3

623.5 kJ …3

[accept either positive or negative answer]

Is the product of this reaction a saturated or an unsaturated hydrocarbon? **3**

saturated …3

Question 12
Answer any two parts. **2×33**

(*a*) Figure 20 shows a laboratory set up to prepare and collect a small, dry sample of a gas. Dilute H_2SO_4 reacts with Na_2SO_3 crystals to produce the colourless, smelly gas. Blue litmus paper first becomes pink and then becomes white in the presence of this gas.

(i) Identify the gas collected. **6**
sulfur dioxide / SO_2 …6

(ii) What is the purpose of the *concentrated* H_2SO_4 in the test-tube labelled X?
dries the gas / absorbs moisture / purifies gas

(iii) How do you know from the method of collection shown in Figure 20 that the gas produced is denser than air? **6, 3**
collected by or diagram shows upwards displacement of air / test tube not inverted / gas collects in test tube / (diagram shows gas) sinks into test-tube
first correct…6, second correct …3

(iv) Is the gas acidic or basic? **6**
acidic …6

(v) What property of the gas causes the litmus paper to become white? **6**
acts as a bleach / reducing reagent …6

(vi) Give one use for the gas. **6**
food preservative / manufacture of sulfuric acid / bleaching paper or wood or straw …6

(*b*) Consider the descriptions in the table relating to covalent bonding in chemical compounds.

A	**Subatomic particles which determine molecular shape**
B	**Pairs of electrons not involved in bonding**
C	**Shared pairs of electrons**
D	**Shape of a water (H_2O) molecule**
E	**Molecule with a pyramidal shape**
F	**Shape of a gaseous beryllium hydride (BeH_2) molecule**
G	**Molecule that has a bond angle of 120°**

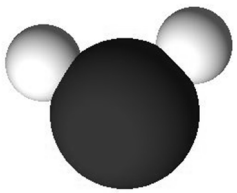
In your answerbook match each term or formula below with its description (A, B, C, D, E, F or G) in the table.

BF_3 electrons linear lone pairs
NH_3 bond pairs v-shaped

4×4, 3, 1, 1

A	electrons		BF_3	G
B	lone pairs		electrons	A
C	bond pairs		linear	F
D	v-shaped		lone pairs	B
E	NH_3		NH_3	E
F	linear		bond pairs	C
G	BF_3		v-shaped	D

Sketch a diagram of the arrangement of atoms in one molecule of water. **9**
v-shaped arrangement shown …9



Why is the bonding in a water molecule described as *polar* covalent? **3**
electrons shared unequally / electronegativity of oxygen greater than that of hydrogen …3

(*c*) Figure 21 shows an example of skywriting which was first used as an advertising medium in the early twentieth century and is still occasionally used. One way of making the white 'smoke' in the sky is to release $TiCl_4$ vapour into a plane's exhaust stream as it manoeuvres to spell out a message.
The $TiCl_4$ reacts with water vapour in the exhaust gases according to the following balanced equation producing particles of solid TiO_2 which form temporary, visible, white trails in the sky.

$$TiCl_{4\,(g)} + 2H_2O_{\,(g)} \rightarrow 4HCl_{\,(g)} + TiO_{2\,(s)}$$

Name the two elements in the compound $TiCl_4$. **2×3**
titanium …3
chlorine …3

What is meant by a *mole* of a substance? **2×3**
SI unit // amount (of a substance) // molecular mass or formula mass …3
of amount (of a substance) // that contains 6×10^{23} particles or atoms or molecules // in grams …3

What is the mass of one mole of $TiCl_4$? **2×3**
48 + (4 × 35.5) …3
= 190 (g) …3

When 19 g of $TiCl_4$ completely reacted with water vapour, calculate

(i) the number of moles of $TiCl_4$ used **3**
(n = 19 ÷ 190 = / $n = \frac{m}{M_r}$) = 0.1 (moles) …3

(ii) the number of moles of water vapour required for the reaction **3**
0.2 (moles) …3

(iii) the mass of TiO_2 produced. **3×3**
0.1 moles TiO_2 …3
M_r TiO_2 = 80 …3
0.1 × 80 = 8 (g) …3
[H = 1; O = 16; Cl = 35.5; Ti = 48]