Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2014

Marking Scheme

PHYSICS & 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, 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 form 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.

Question 1
Any eleven parts **11×6**

(*a*) **Which of the following are vector quantities?**
force energy momentum mass speed **5, 1**
force
momentum

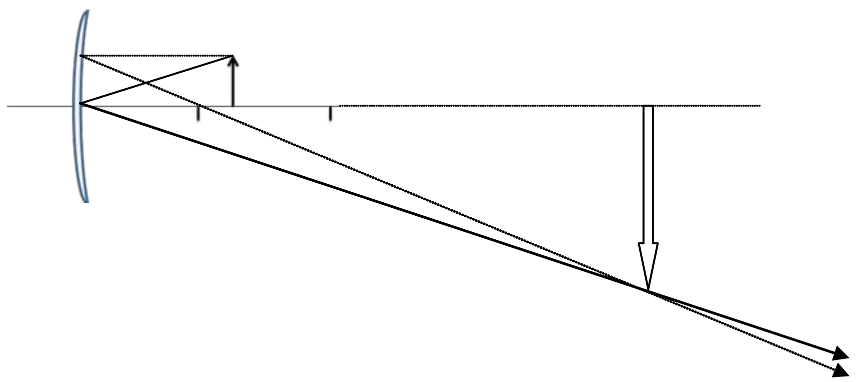
first correct …5
second correct…1

(*b*) **What quantity is defined as *the change in velocity per unit time*?**
What unit is assigned to this quantity? **2×3**
acceleration …3
m s^{-2} / m / s^2 …3
[m s^2 or m/s $^{-2}$ ...(–1)]

(*c*) **A body moving in a straight line with a speed of 10 ms^{-1} had kinetic energy of 1500 J. When its speed increased to 40 m s^{-1} what was its new kinetic energy?** **2×3**
$\frac{E_2}{E_1} = \frac{\frac{1}{2}mv_2{}^2}{\frac{1}{2}mv_1{}^2} = \frac{v_2{}^2}{v_1{}^2} = \frac{1600}{100}$ / $E_2 = 16 \times E_1$ …3
$E_2 = 1500 \times 16 = 24000$ (J) …3
or
$E_1 = ½mv_1{}^2$ / $m = 2\ E_1 \div v_1{}^2$ / $m = 30$ (kg) ...3
$E_2 = ½mv_2{}^2 = ½ \times 30 \times 40^2 = 24000$ (J) ...3

(*d*) **State the principle of *conservation of momentum*.** **2×3**
(in a system of colliding bodies) where no external force acts (total) momentum or *mv* //
(in a system of colliding bodies) where no external force acts the (total) momentum before a collision//
(in a system of colliding bodies) where no external force acts $m_1u_1 + m_2u_2 =$ …3
is constant //
is equal to total momentum after //
$m_1v_1 + m_2v_2$ or $(m_1 + m_2)v$ …3
[where no external force acts omitted…(–1)]

(*e*) **Copy Figure 1 and complete it as a ray diagram showing the formation of the image of an object O placed between the focus F and the centre of curvature C of a concave mirror.** **5, 1**



first correct ray …5
second correct ray intersecting first to form image …1

(*f*) **What is meant by the *dispersion* of white light?** **2×3**

breaking up / splitting (of white light) …3

into its constituent colours / into different wavelengths / into a list of colours / into a spectrum/into a rainbow …3

(*g*) **What is the photoelectric effect?** **2×3**

the emission of electrons from the surface of a metal / the emission of electrons from zinc …3

when light or electromagnetic radiation of a suitable frequency falls on it / when u.v. light falls on it …3

[surface omitted...(–1)]

(*h*) **Calculate the energy of a photon of gamma radiation that has a frequency of 3.9 ×10^{22} Hz.** **2×3**

$E = hf \,/\, E = \dfrac{hc}{\lambda}$ ..3

$E = 6.626 \times 10^{-34} \times 3.9 \times 10^{22} = 2.58 \times 10^{-11}$ (J) ...3

(*i*) **What is *Brownian motion (movement)*?** **2×3 or 6**

rapid /continuous / random / straight line / zig-zag motion of small particles or molecules ...3

any two... 2×3

or

movement of visible particles / molecules due to collisions with invisible particles / molecules (in a liquid or gas) suspended in air or liquid …6

[accept information given in a labelled diagram][example only...(–3)]

[‘particles’ omitted...(–1)]

(*j*) **What is a thermometric property? Give an example.** **2×3**

(a property which) changes (continuously or measurably) with temperature or degree of hotness …3

volume or height of liquid (in a column), volume of gas (at constant pressure), pressure of a gas (at constant volume), product of pressure and volume of a gas, emf (generated in a thermocouple), resistance (of metal or thermocouple), colour, etc. any one…3

(*k*) **A sample of gas had an initial volume of 213 cm^3 at a temperature of 300 K. The temperature of the gas fell to 200 K without change of pressure. What was the new volume of the gas?** **2×3**

$\frac{V_1}{T_1} = \frac{V_2}{T_2} \,/\, \frac{V}{T}$ constant / $\dfrac{V}{T} = k$ ...3

$V_2 = \frac{200 \times 213}{300} = 142$ (cm^3) ...3

[any other form of 142...(–1)]

(*l*) **State *Coulomb’s law* of force between electric charges.** **2×3**

the force (between two point charges) is directly proportional to the product of the charges …3

and inversely proportional to the distance between them squared …3

[square omitted (−3)][word ‘product’ omitted (−1)][sum instead of product of charges (−3)]

or

$F \propto \dfrac{Q_1 Q_2}{d^2}$ // $F = \dfrac{kQ_1 Q_2}{d^2}$ // $F = \dfrac{1}{4\pi\varepsilon}\dfrac{Q_1 Q_2}{d^2}$

[omit to explain F, Q_1, Q_2, d, ε …(–1)]

(*m*) **Two long light conducting wires A and B hang freely, side by side, but not touching as shown in Figure 2.**
Why do the wires move when parallel currents *I* are passed through the wires? **<u>6</u>**
magnetic field created around each wire / a magnetic force is exerted on each wire
[force between wires…3] [wires attract / repel each other…3] …6

(*n*) **What is meant by *nuclear fission*?** **<u>2×3</u>**
breaking up / splitting of a large nucleus …3
into two (smaller) nuclei …3
[atom instead of nucleus…(–1)][large omitted…(–1)][into two or more…(–1)]
[into smaller nuclei…(–1)]

(*o*) **Give <u>two</u> properties of a beta particle.** **<u>5, 1</u>**
negatively charged or charge of minus one, electrons, high speed particles, moderately penetrating, moderately ionizing, deflected in an electric field, deflected in a magnetic field, negligible mass or very small mass or 1/1840 amu, speeds of 30 - 70% speed of light, etc.

first correct …5
second correct…1

Question 2

(*a*) Define

(i) work **2×3**

work is done when a force // F // Force …3

moves its point of application // × s // × distance …3

[omit to explain F, s (−1)]

(ii) power **2×3**

work done / energy used // rate of doing // W or E // force // F …3

per second / per unit time // work // ÷ t // × velocity // × v …3

[omit to explain W or E, t , F, v (−1)]

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

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

to applied force and in the same direction // F and in the same direction …3

[omit in the same direction...(−1)] [omit to explain F, m, v, u, t ...(−1)]

[$F = ma$ …3, omit to explain F, m, a ...(−1)]

(*c*) Draw a labelled diagram of an apparatus used to measure the acceleration caused by an applied force. **4×3**

trolley on track ..3

sloped track or on a smooth frictionless horizontal track, e.g air track …3

attached to weights or masses by string passing over pulley / attached to spring balance …3

timing using ticker tape timer, light gates, powder track, picket fence timer, etc …3

[no labels…(−3)]

[ticker tape instead of ticker (tape) timer...(−1)]

State

(i) one precaution taken to minimise the effects of friction. **3**

sloped track (to compensate for friction) / polish track / use air-track /
clean or oil trolley wheels / clean track (to reduce friction due to dust) / use a pulley

any one…3

(ii) how the applied force was measured **3**

known weights / known mass × g / spring balance any one …3

[known masses...(−1)]

(iii) how the timing system was used to measure the initial velocity **2×3**

record time t for card to pass through first light gate / measure length of card / count dots or spaces or powder patches corresponding to s / t = number of spaces ÷ 50 ...3

initial velocity = u = distance ÷ time ...3

[marks may be awarded for information provided **clearly** in the diagram]

(*d*) The motion of an object of mass 1.5 kg on a smooth horizontal surface is represented by the graph in Figure 3 and consists of two parts A (first 3 seconds) and B (final 2 seconds), as indicated.
For part A of the motion, use the data in Figure 3 and the equations of motion, to calculate
(i) the acceleration of the object **2×3**

$v = u + at$ / $a = \dfrac{v-u}{t}$ / a = slope of graph …3

$\Rightarrow a = \dfrac{18-0}{3} = 6$ m s^{-2} …3

[no unit or incorrect unit (−1)]

(ii) the force applied to the object **3**
$F = ma = 1.5 \times 6 = 9$ N …3
[no unit or incorrect unit (−1)]

(iii) the work done **2×3**
$W = E = ½mv^2$ ...3
= ½ × 1.5 × 18^2 = 243 J ...3

or

$s = ut + ½at^2$ / $s = \dfrac{v^2 - u^2}{2a}$ / s = 27 (m) …3
work = force × displacement / $W = Fs$ / W = 9 × 27 = 243 J …3
[no unit or incorrect unit (−1)] [incorrect calculations or no calculations...(−1)]

(iv) the power developed. **3**
power $= \dfrac{work}{time} = \dfrac{energy}{time}$ / $P = \dfrac{W}{t} = \dfrac{E}{t}$ / $P = F \times v$ / $P = \dfrac{243}{3} = 81$ W …3
[no unit or incorrect unit (−1)] [incorrect calculations or no calculations...(−1)]

For part B of the motion what is
(v) the distance travelled **3**
distance = speed × time / $d = v \times t$ / $d = 18 \times 2 = 36$ m …3
[no unit or incorrect unit (−1)] [incorrect calculations or no calculations...(−1)]

(vi) the force acting on the object? **3**
$F = 0$ / (force is) zero / no force acts (because velocity is constant) …3
[acceleration zero ....allow 2]

Question 3

(*a*) What is refraction of light? **5, 1**

bending / deflection / changing direction …5

(of light) as it passes from one medium to another (of a different optical density) …1

State *Snell's law of refraction.* **2×3**

sine the angle of incidence or sin *i* //

(ratio of) sine of angle of incidence to sine of angle of refraction or $\frac{\sin i}{\sin r}$ …3

is proportional to sine angle of refraction or $\propto$ sin *r* //

is constant or equal to refractive index or *n* or *μ* …3

[sines omitted...(−1), reflection instead of refraction…(−3), no need to explain *i* or *r*]

(*b*) Light travels along perspex optical fibres by *total internal reflection*.

(i) Define total internal reflection. **6**

(occurs when) angle of incidence in the more dense medium exceeds the critical angle …6

['in more dense medium' omitted …(–1)]

(ii) Give one application of optical fibres. **3**

(tele)communications / transmission of data or phone calls / in medicine in instruments used to view internal body parts / keyhole laser surgery / sensors, etc

any one…3

A student measured the angle of incidence *i* and the corresponding angle of refraction *r* for a ray of light entering a semi-circular perspex block at O and emerging again at A as shown in Figure 4.

This procedure was repeated for different angles of incidence *i* and the following results were obtained.

***i* (degrees)**	**5**	**15**	**25**	**35**	**45**	**54**	**63**
***r* (degrees)**	**3**	**10**	**17**	**23**	**28**	**33**	**36**

(*c*) Using the data above, draw a suitable graph to verify Snell's law. **5×3**

calculate sin*i* and sin*r* for all values …3

sin *i*	0.09	0.26	0.42	0.57	0.71	0.81	0.89
sin*r*	0.05	0.17	0.29	0.39	0.47	0.54	0.59

axes correctly labelled sin*i* and sin*i* …3

axes drawn with appropriate scales …3

five points correctly plotted …3

straight line through these points and through (or very close to) origin ...3

[max 9 if graph is not on graph paper]

[max 9 if *i* versus *r* graphed]

Explain how the graph verifies Snell's law **3**

straight line through origin …3

(*d*) Use your graph to find the refractive index of the perspex **3×3**

choose two points on the graph (x_1, y_1) and (x_2, y_2) and calculate $y_2 - y_1$ …3

calculate $x_2 - x_1$ …3

slope = $\frac{y_2 - y_1}{x_2 - x_1}$ = approx 1.5 …3

[accept values 1.48 – 1.52]

(*e*) **Calculate the critical angle for the perspex.** **<u>2×3</u>**

$$\frac{1}{SinC} = 1.5$$ …3

sin$C$ = 0.6667 $\Rightarrow c = 41.8^{\circ}$ …3

(*f*) **Calculate the speed of light in the perspex.** **<u>2×3</u>**

$n = \frac{c_1}{c_2}$ / $n = \frac{2.998 \times 10^8}{c_2}$ / $\frac{3.0 \times 10^8}{c_2}$ ...3

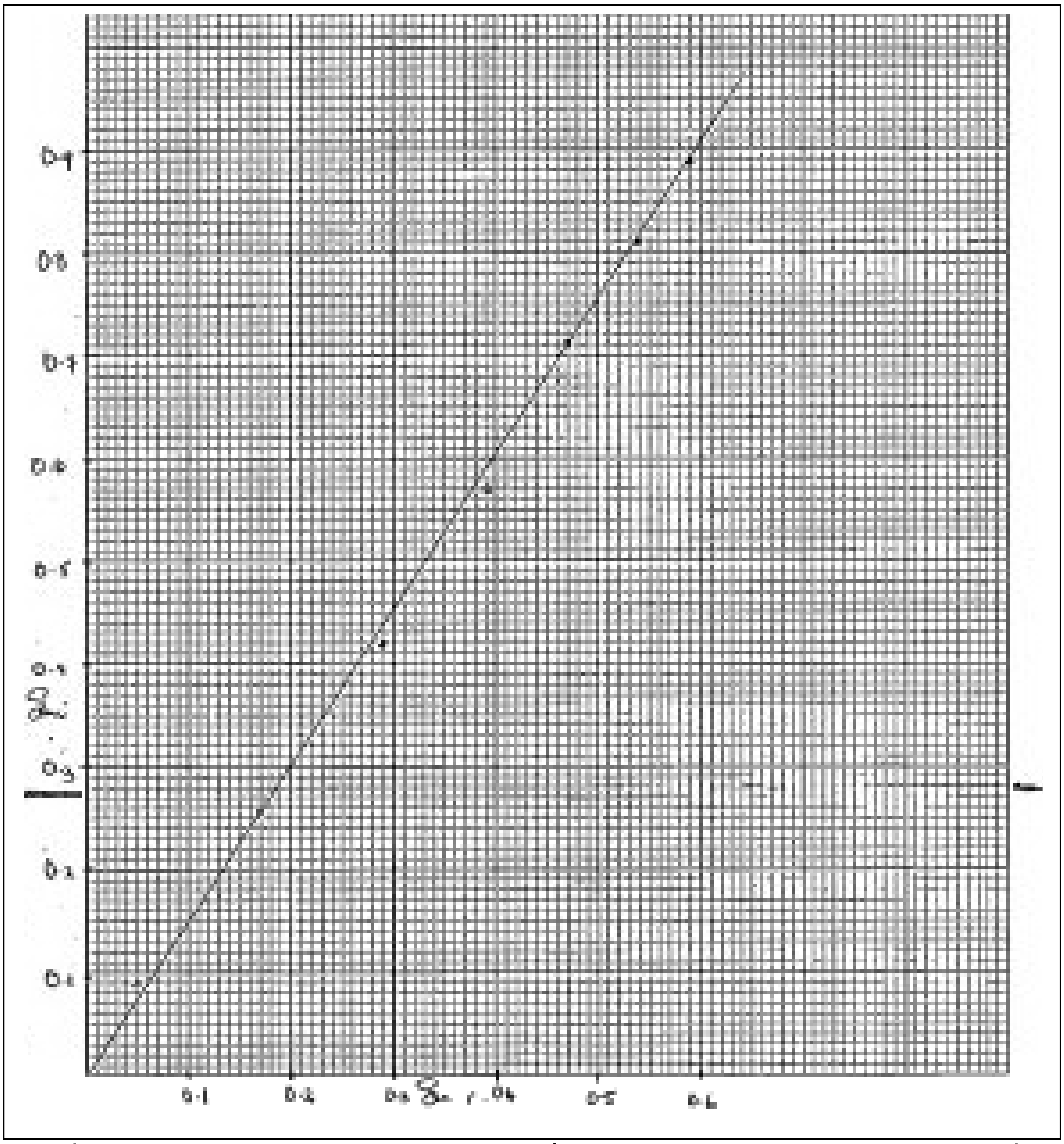
$c_2 = \frac{2.998 \times 10^8}{1.5}$ / $\frac{3.0 \times 10^8}{1.5}$ = 1.999×10^8 m s^{-1} / [1.99×10^8 m s^{-1} − 2.0×10^8 m s^{-1}] ...3

[no unit or incorrect unit …(−1)]

(*g*) **Why does refraction <u>not</u> occur at A as the ray emerges from the perspex?** **<u>6</u>**

ray of light strikes the boundary (between the two media) at right angles / perpendicularly / normally / ray exits along a radius …6

[reference to ray exiting at semi-circular or curved surface ...allow 3]



Question 4

(*a*) State *Boyle's law*. **2×3**

the pressure of a (fixed) mass of gas …3
is inversely proportional to its volume at constant temperature …3

or

p // pV // p_1V_1 ...3
$\propto 1/V$ // is a constant or $= k$ // $= p_2V_2$ at constant temperature ...3
[omit to explain p and V…(−1)] [at constant temperature omitted …(−1)]

Draw a labelled diagram of an apparatus used to investigate Boyle's law. **3×3**

fixed volume of gas shown in diagram …3
scale to read volume shown …3
pressure gauge / device to read pressure …3
[no labels …(−3)]

What measurements were taken? **3**

pressure and (corresponding) volume …3
[marks can be obtained from diagram]

How were these measurements used to verify Boyle's law? **3**

graph of pressure or p versus $1/V$ a straight line through the origin / pV = constant value …3

(*b*) Define the ideal gas. **2×3**

the gas that obeys the gas laws or Boyle's law / satisfies assumptions of the kinetic theory …3
at all temperatures and pressures / under all conditions …3

State one way that the behaviour of a real gas differs from the behaviour of the ideal gas. **3**

molecules of a real gas have volume or are not point masses,
molecules of the ideal gas are point masses /

attractive forces between molecules of a real gas, no forces between molecules of the ideal gas /
real gases condense, the ideal gas never condenses /

collisions in a real gas not elastic,
collisions in the ideal gas are elastic /

in a real gas the size of the particles are not negligible compared to spaces between them,
in the ideal gas the size of particles is negligible compared to spaces between them /

molecules of a real gas do not obey Boyle's law at all temperatures and pressures,
molecules of the ideal gas obeys Boyle's law under all conditions

[opposite may be inferred]

any one …3

Under what conditions does a real gas behave most like the ideal gas? **5, 1**

high temperatures
low pressures

first correct …5
second correct…1

[reversed allow 3]

What property of a gas is determined by the average kinetic energy of its molecules? **3**
temperature …3
[cancellation does *not* apply where pressure or volume also given]

(*c*) Explain the terms
(i) *absolute zero* of temperature **9**
lowest temperature possible or which exists or theoretical / temperature where (the ideal) gas has zero volume or no kinetic energy / (temperature at which) the movement of molecules or particles is minimal or stopped /
[0 K or −273 °C allow 6] …9

(ii) *triple point of water*. **2, 1**
temperature (and pressure) …1
at which ice, water and water-vapour co-exist (in equilibrium) ...2

What value is assigned to the triple point of water on the Kelvin temperature scale? **3**
273.16 K …3
[273.15 K (−1)]

The pressure recorded using a constant volume gas thermometer at the triple point of water was 8.25 kPa. The pressure recorded at room temperature was 9.00 kPa.
What was the temperature in the room? **2×3**

$$\frac{T}{T_{tp}} = \frac{P_t}{P_{tp}}$$ …3

$$\frac{T}{273.16} = \frac{9.0 \times 10^{-3}}{8.25 \times 10^{-3}} = \frac{9.0}{8.25}$$

$$\Rightarrow T = \frac{9.0 \times 273.16}{8.25}$$ = 298 K or 25 °C …3

Give one advantage of a constant volume gas thermometer compared to other thermometers. **6**
more accurate / wider range / greater sensitivity / can be used as a standard thermometer
any one …6

Question 5

(*a*) State *Ohm's law*. **2×3**

at constant temperature current // at constant temperature *V* …3

is proportional to potential difference // = *IR* / ∝ *I* …3

[accept equivalent statements with current and potential difference reversed]

[omit at constant temperature …(−1), omit to explain terms …(−1)]

Distinguish between alternating current (a.c.) and direct current (d.c.). **2×3**

a.c. or charge carriers or electrons reverse(s) direction periodically (when flowing in a circuit) / a.c. or charge carriers or electrons flow(s) to and fro or oscillate(s) (in a circuit) …3

d.c. flows in one direction (in a circuit) …3

[examples of both...3][accept diagrams …3, labelled … 3]

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

when a conductor moves relative to a magnetic field / when magnetic lines of flux are cut /when magnetic flux changes …3

an electric current is induced (in it) / an emf is induced (in the conductor) …3

Fleming's right hand generator rule is used to determine the direction of the induced current in a conductor as shown in Figure 5.

Name the quantities represented by the arrows A, B and C. **3×3**

A (thumb) = motion …3

B (forefinger) = magnetic field …3

C (second finger) = (induced) current …3

[three correct names all assigned incorrectly ...6, three correct names with two reversed ...7]

(*c*) Figure 6 shows a step-down transformer. Explain the operation of a transformer. **2×3**

a.c. or alternating current or changing emf or changing current in primary coil / induces or produces a current or emf in the secondary / by electromagnetic induction /

output voltage or current depends on the ratio of turns in secondary to turns in primary /

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} \,/\, \frac{N_p}{N_s} = \frac{I_s}{I_p}$$

any two…2×3

State one cause of energy loss in a transformer. **6**

heat losses (in the coils) / eddy currents / energy lost in magnetising and demagnetising the core or hysteresis losses / leakage of magnetic flux / coils not tightly wound / energy lost as sound or vibration

any one…6

(*d*) The step-down transformer in a mobile phone charger converts a 230 V a.c. mains supply to a 5 V a.c. output.

How many turns are required in the secondary coil of the transformer to give the 5 V output if the 230 V mains supply flows through 460 turns in the primary coil? **2×3**

$$\frac{n_s}{n_p} = \frac{V_s}{V_p}$$ …3

$$\frac{n_s}{460} = \frac{5}{230} \Rightarrow n_s = 10$$ …3

The transformer output is then converted to a 5 V direct current in order to charge the battery of the phone. The circuits of the charger and the connected phone have a *combined* resistance of 4.5 Ω.

Calculate

(i) the current flowing in the circuits of the charger and connected phone **<u>2×3</u>**

$V = IR \;/\; \frac{V}{I} = R \;/\; I = \frac{V}{R}$ …3

$I = \frac{5}{4.5} = 1.1$ A …3

[no unit or incorrect unit …(−1)]

(ii) the power used when the phone is connected and charging **<u>2×3</u>**

$P = VI$ …3

$P = 5 \times 1.1 = 5.5$ W …3

[no unit or incorrect unit …(−1)]

(iii) the energy wasted in one week by a charger left on 'stand-by' 80% of the time while still using 0.125 W. **<u>3×3</u>**

energy = power × time / $E = Pt$ / $H = I^2Rt$ ...3

$t = 7 \times 24 \times 60 \times 60 \times 0.8 = 483840$ (s) // $t = 7 \times 24 \times 60 \times 60 = 604800$ s …3

$E = 0.125 \times 483840 = 60480$ J / 60.48 kJ // $E = 0.125 \times 604800 \times 0.8 = 60480$ J or 60.48 kJ …3

[no unit or incorrect unit …(−1)]

Question 6
<u>Answer any two parts.</u>

Question 6(*a*)
State *Newton's law of universal gravitation.* **<u>2×3 or 6</u>**
force between two (point) masses is proportional to the product of the (two) masses …3
(and) inversely proportional to the square of the distance between them …3
[square omitted…(−3)][word 'product' omitted…(−1)][sum instead of product of masses…(−3)]

or

$F \propto \frac{m_1 m_2}{d^2}$ / $F = \frac{G m_1 m_2}{d^2}$ ...6

[omit to explain F, m_1, m_2, G, d…(−1)][square omitted …(−3)][sum instead of product…(−3)]
[accept relationship between g and G for…3]

Two uniform lead spheres A and B of different sizes and whose surfaces touch are shown in Figure 7. The mass of A is 64 times the mass of B and the density of lead is 1.13×10^4 kg m^{-3}.
Calculate
(i) the mass of sphere A whose volume is 0.0042 m^3 **<u>2×3</u>**
mass = volume × density / $m = V \times \rho$ …3
mass = $0.0042 \times 1.13 \times 10^4 = 47.46$ kg …3
[no unit or incorrect unit …(−1)]

(ii) the gravitational force between the two spheres when they are in contact. **<u>5×3</u>**
$F = \frac{G m_1 m_2}{d^2}$ …3
$d = 0.1 + 0.025 = 0.125$ (m) …3
$m_2 = 47.46 \div 64 = 0.74$ (kg) /
m_2 = volume × density = $\frac{4}{3}\pi r^3 \times 1.13 \times 10^4 = \frac{4}{3}\pi(0.025)^3 \times 1.13 \times 10^4 = 0.74$ kg …3
$F = \frac{6.6742 \times 10^{-11} \times 47.46 \times 0.74}{0.125^2}$ …3
$= 1.5 \times 10^{-7}$ N …3
[no unit or incorrect unit …(−1)]

How would you expect the gravitational force between the two spheres to change as they are moved apart? **<u>3</u>**
decrease …3

Justify your answer. **<u>3</u>**
as d increases F decreases, etc …3

Question 6(*b*)

Define *capacitance*. **2×3**

ratio of charge to // *Q* ÷ …3

potential or voltage // *V* …3

[omit to explain *Q*, *V*, *C*…(−1)]

Describe an experiment to show how the capacitance of a parallel-plate capacitor depends on the distance between its plates. **3×3**

parallel plate capacitor, electroscope or GLE, drawn or described …3

move plates towards or away from each other …3

plates moved apart leaves diverge, potential difference (p.d). or voltage increases so capacitance decreases / plates moved towards each other leaves collapse, potential difference (p.d.) or voltage decreases so capacitance increases …3

Calculate the effective capacitance of the combination of capacitors shown in Figure 8. **2×3**

12 + 8 = 20 μF …3

$\frac{1}{C} = \frac{1}{20} + \frac{1}{4} = \frac{3}{10} \Rightarrow C = 3.33\ \mu F$ …3

[no unit or incorrect unit …(−1)]

[failure to invert $\frac{1}{C}$ ...(−1)][reversal of formulae...(−3)]

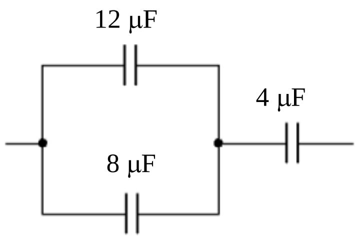


Figure 8

The charge stored in the capacitor in a defibrillator can be used to shock the heart of a person in cardiac arrest back into a normal rhythm. What charge is stored in a 32 μF capacitor in a defibrillator when it is connected to a 500 V supply? **2×3**

$C = \frac{Q}{V} / Q = CV$ …3

$Q = 32 \times 10^{-6} \times 500 = 0.016$ C or 16000 μC …3

[no unit or incorrect unit …(−1)]

Give one other use for a capacitor. **6**

storage of charge or energy (electrostatically) / tuning radio or TV to different stations / to separate a.c. from d.c. / to operate a tuning circuit / to smooth output from rectifier / touch screen of smartphone or tablet device, etc

any one …6

Question 6(*c*)

<u>Diffraction</u> and <u>interference</u> both occur when a narrow beam of red <u>monochromatic light</u> passes through a pair of narrow slits whose separation is 0.3 mm. The light then strikes a screen 2.4 m from the slits forming a pattern of bright and dark images. The distance from the central bright image to the 6th bright image is 3.12 cm as shown in Figure 9.

Explain the underlined terms. **<u>5×3</u>**

diffraction is the spreading out / bending of a wave …3

as it passes behind an obstacle / through a (narrow) gap / into the geometric shadow of an obstacle/around a corner …3

[good diagram…3 × 2]

interference occurs when two (or more) waves …3

superimpose / meet …3

[good diagram…3 × 2]

monochromatic light is light of a single frequency / one wavelength / one colour …3

Calculate the wavelength of the red light used. **<u>4×3 or 6, 2×3</u>**

$n\lambda = d\sin\theta$ …3

$$\tan\theta = \frac{3.12\times10^{-2}}{2.4} = 0.013$$ ...3

$\sin\theta \approx \tan\theta = 0.013$ / $\tan^{-1} = 0.7448^{\circ} \Rightarrow \sin\theta = 0.013$ ...3

$6\lambda = 0.3 \times 10^{-3} \times 0.013$

$\lambda = 6.5 \times 10^{-7}$ m or 650 nm ...3

[no unit or incorrect unit …(−1)][$\tan\theta = 1.3$ …(−1)]

or

$$n\lambda = \frac{dx}{D}$$

$$6\lambda = \frac{0.3\times10^{-3}\times3.12\times10^{-2}}{2.4}$$ ...6

...3

$\lambda = 6.5 \times 10^{-7}$ m or 650 nm ...3

[no unit or incorrect unit …(−1)][failure to convert mm to m...(−1)][failure to convert cm to m...(−1)]

What did Thomas Young conclude about the nature of light, when he pioneered this experiment in 1802? **<u>6</u>**

light has a wave nature / light is not composed of particles …6

Question 6(*d*)

Define the *half-life* of a radioactive isotope. **2×3**

time taken for …3

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

Use the graph in Figure 10 to estimate the half-life of radon–222, an alpha particle emitter. **6**

3.8 days ...6

[accept 3.8 to 4 days]

What is an alpha particle? **2×3**

helium / He / ${}^{4}_{2}He$ // protons and neutrons …3

nucleus / dipositive ion / with dipositive charge // two of each …3

***Fracking* is the process of drilling and injecting fluid at high pressure into the ground to release natural gas and oil trapped in rock. Radon–222 sometimes occurs in rocks as a result of the radioactive decay of uranium–238. Radon-222 gas could be released into the environment as a result of fracking.**

Starting with one U–238 nucleus, how many
(i) alpha particles, (ii) beta particles, are released in the production of one Rn–222 nucleus by radioactive decay? **3×3**
Refer to pages 79 and 82 of the *Formulae and Tables* booklet.

(i) 238 – 222 = 16 …3

16 ÷ 4 = 4 alpha particles …3

(ii) 92 – 8 = 84 and 86 – 84 = 2

2 beta particles …3

State one way that a radioactive gas like radon–222 can damage human tissue. **6**

cancer / tumours / DNA damage / mutations / burning, etc

any one…6

Question 7
Any eleven parts **11×6**

(*a*) **In a crystal of potassium chloride (KCl), an ionic compound, identify (i) the particles that occupy the lattice points, (ii) the forces that bind these particles together.** **2×3**
ions …3
ionic bonds / electrostatic forces / force between oppositely charged ions …3

(*b*) **What name is given to the energy change represented by the following equation?**

$$\mathbf{X_{(g)} \rightarrow X^{+}_{(g)} + e^{-}}$$

2×3
first ...3
ionisation energy ...3

(*c*) **Define a *mole* of a chemical.** **2×3**
contains same number of particles // has 6×10^{23} or Avogadro's number // has same mass as // SI unit for …3
as 12 g of C–12 // of particles // molecular mass in grams / gram molecular mass of a substance // amount or quantity of a substance …3
[12 g of C (–1)]

(*d*) **Give a reason why the atomic radii of the elements in the periodic table (i) decrease across a period, (ii) increase down a group.** **2×3**
(i) increasing nuclear charge / more protons in nucleus (with no shielding increase) ...3
(ii) extra energy level added / energy level increase / extra shell added / outer electron further from nucleus / increased shielding or screening ...3

(e) **Balance the following chemical equation.**
$\mathbf{Al + HCl \rightarrow AlCl_3 + H_2}$ **6**
$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$ ...6
[first element balanced ….3, three balanced…6] [accept division by two]

(*f*) **Explain why boron trifluoride (BF_3) does not have a dipole moment.** **2×3**
centres of charge // dipole (moments) // symmetrical ...3
coincide // cancel // arrangement of bonds in 3d space about central atom …3

(*g*) ***Superglue* is the trade name for methyl-2-cyanoacrlyate ($C_5H_5NO_2$). It is used in forensic science to help make hidden fingerprints visible as shown in Figure 11. Calculate the percentage by mass of the element oxygen in methyl-2-cyanoacrylate.**
[H = 1; C = 12; N = 14; O =16] **2×3**
(M_r =) 111 ...3
(% oxygen =) $\frac{2\times16}{111}\times 100 = 28.83\%$ [28.83 – 29] ...3

(*h*) **Give two chemical properties associated with transition metals or their compounds.** **5, 1**
variable valency / good catalysts / form coloured compounds / partially filled *d*-sublevel
first correct …5
second correct…1

(*i*) **Write the names or formulae of two compounds that contain both hydrogen and oxygen only.** **5, 1**
H_2O / water
H_2O_2 / hydrogen peroxide
first correct …5
second correct…1

(*j*) **Identify (i) the conjugate acid of NH_2^- (ii) the conjugate base of H_3O^+.** <u>**5, 1**</u>

NH_3
H_2O
[charge incorrect (–1)]

first correct …5
second correct…1

(*k*) **Distinguish between an *exothermic* and an *endothermic* reaction.** <u>**6**</u>

exothermic reaction gives out heat and endothermic reaction absorbs heat /
ΔH positive for an exothermic reaction and ΔH negative for an endothermic reaction …6
[opposite not given...(–1)]

(*l*) **Define *heat of formation* of a substance.** <u>**2×3**</u>

heat change when one mole (of a compound) is formed …3
from its elements in their standard state ...3
[in standard state omitted...(–1)][heat involved...(–1)]

(*m*) **What is the functional group in (i) an aldehyde, (ii) a ketone?** <u>**5, 1**</u>

(i) CHO
(ii) C=O

first correct …5
second correct…1

(*n*) **Name <u>two</u> of the aromatic compounds labelled A, B, C in Figure 12.** <u>**5, 1**</u>

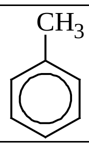
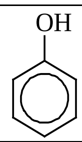
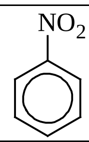
A	**B**	**C**
		

Figure 12

A = methylbenzene / toluene
B = phenol / hydroxybenzene
C = nitrobenzene

first correct …5
second correct…1

(*o*) **Propyl ethanoate ($CH_3COOC_3H_7$) is an ester that has the odour of pears. What two substances react to form propyl ethanoate?** <u>**5, 1**</u>

propan-1-ol / propanol /C_3H_7OH
ethanoic acid / CH_3COOH

first correct …5
second correct…1

Question 8

Atoms of carbon exist as isotopes, e.g. carbon–12, carbon–14. The element carbon occurs in different allotropic forms, e.g. graphite, diamond.

(*a*) Define (i) *mass number* **6**

number of protons and neutrons ...3

in the nucleus / in an atom …3

(ii) *relative atomic mass* **6**

mass of an atom of an element relative to // average mass number of all the isotopes …3

1/12 the mass of the C–12 isotope // taking their natural abundances into account …3

[atom omitted...(–1)][average omitted...(–1)]

Explain why the relative atomic mass of naturally occurring carbon is not a whole number. **3**

natural carbon occurs as mixture of isotopes / natural carbon is mostly carbon–12 but there are small quantities of other isotopes also / relative atomic mass is the average mass of all the isotopes …3

(*b*) Write the electron configuration (*s*, *p*) for a carbon atom. **2×3**

$1s^2\ 2s^2$ …3

$2p^2$ / $2p_x^{\,1}\ 2p_y^{\,1}$ …3

(*c*) Use dot and cross diagrams to show the bonding in a molecule of methane (CH_4). **6**

diagram showing C bonded to 4 hydrogens by 4 single covalent bonds ...6

State and explain the bond angle in a methane molecule. **2×3**

109.5° …3

no lone pairs, four bonding pairs as far away from each other as possible /
four bonding pairs arranged tetrahedrally …3

[109...(–1)]

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

measure of attraction / relative attraction / measure of the force of attraction …3

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

[force of attraction (–1)]

Identify the type of bond that occurs in a water molecule. **3**

polar covalent bond …3

[covalent (–1)][polar...(–1)]

Predict the solubility or otherwise of methane in water, justifying your answer in terms of bonding. **2×3**

methane is not soluble in water / methane has very low solubility in water …3

methane is a non-polar molecule and water is a polar molecule / there is no attraction between the (polar) water molecules and the(non-polar) methane molecules / …3

[allow ‘like dissolves like’ if there is some reference to water and methane having different bonding ...3] (*e*) **Figure 13 shows parts of the crystal structures of diamond (A) and graphite (B)**

What type of bond holds the carbon atoms together in diamond? **<u>3</u>**
(pure, non-polar) covalent bond ...3

In graphite, what type of bonding force holds

(i) the carbon atoms together within each layer **<u>3</u>**
(pure, non-polar) covalent bonds …3

(ii) the layers together? **<u>6</u>**
van der Waals forces …6

Which of these two allotropes is a good electrical conductor? **<u>3</u>**
graphite ...3

Explain how electricity is conducted through this allotrope. **<u>3</u>**
(valence) electrons free to move / (valence) electrons delocalised …3

Question 9

To determine the concentration of a barium hydroxide ($Ba(OH)_2$) solution, a student titrated it in 25.0 cm^3 volumes against a 0.18 M solution of hydrochloric acid (HCl). On average, 23.08 cm^3 of the hydrochloric acid solution was required for neutralisation. Because hydrochloric acid is not a primary standard, it had been previously standardised by titrating it with a suitable primary standard base.

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

(exact mass of) pure / stable / high molecular weight / soluble solid (used to give a) ...3
solution of known concentration ...3
[‘solid’ omitted...(–1)]

Name a suitable primary standard used to standardise the hydrochloric acid solution. **3**

anhydrous sodium carbonate / Na_2CO_3 ...3
[anhydrous omitted… (–1)][$NaCO_3$...(–1)]

(*b*) Having rinsed a 25.0 cm^3 pipette with deionised water for use in the titration, why was it then rinsed with a little of the solution it was to deliver? **3**

to remove water ...3

Figure 14 shows the level of solution in the pipette before it was released into a titration flask. Explain whether the pipette had been filled correctly to 25.0 cm^3. **2×3**

yes ...3
bottom of meniscus on the (graduation) mark read at eye level ...3
[‘read at eye level’ omitted ….(–1)]

Describe the procedure for transferring exactly 25.0 cm^3 of solution to a titration flask from this pipette assuming it has been correctly filled. **5, 1**

allow to drain (under gravity) / wait a few seconds at the end of drainage /
do not blow out or shake out the last drop / touch tip of pipette against wall of titration flask (to remove any drop clinging to the outside)

first correct …5
second correct…1

(*c*) Give a reason why

(i) a *conical* flask is suitable for use as the titration flask. **6**

sides can be washed down easily /
allows swirling / prevents splashing ...6

(ii) the sides of the conical flask were washed down with deionised water a few times during the titration **6**

to remove any drops of solution clinging to the inside wall of the flask /
to ensure all the solution will react ...6

(iii) the conical flask may have been placed on a white tile during the titration. **3**

to allow colour change (at end point) to be seen easily / to allow the end point be found accurately ...3

(*d*) Barium hydroxide is a strong base.
Name an indicator suitable for this titration. **3**

methyl orange // phenolphthalein // litmus ...3

State the colour change observed at the end point. **2×3**

yellow or orange to // pink or purple to // blue or purple to ...3
orange or pink or peach or red // colourless // purple or red ...3
[allow max 3 if colours are inconsistent with named indicator or reversed]

(*e*) Write a balanced equation for the titration reaction. **<u>2×3</u>**

$Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$ ...6

products correct ...3

balanced ...3

[accept own balanced equation for 3]

(*f*) Calculate the concentration of the barium hydroxide solution in (i) moles per litre **<u>2×3</u>**

$$\frac{M_1V_1}{n_1} = \frac{M_2V_2}{n_2} \;/\; \frac{25 \times M_1}{1} = \frac{23.08 \times 0.18}{2} \;/$$

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

(M_1) = 0.083 (M) ...3

(ii) grams per litre. **<u>2×3</u>**

M_r $Ba(OH)_2$ =171 (137 + 32 + 2) ...3

0.083 × 171 = 14.19 (g /L) ...3

Question 10

(*a*) Define (i) oxidation, (ii) reduction, in terms of electron transfer. **2×3**

oxidation is the loss of electrons …3

reduction is the gain of electrons …3

(*b*) When lead sulfide (PbS) is roasted in air, lead oxide (PbO) is formed. When lead oxide is heated with coke (C), lead (Pb) metal is obtained.

Identify the oxidising agent in each of these reactions given by the following equations. **2×3**

$$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$$

$$2PbO + C \rightarrow 2Pb + CO_2$$

oxygen / O_2 …3

Pb /PbO …3

(*c*) Arrange the following metals in order of *ease of oxidation.*

gold sodium copper aluminium lead

2×3

sodium first and gold last ...3

aluminium, lead, copper in correct order …3

[correct sequence of all 5 but reversed (–1)][first and last reversed (–1)]

Which of these metals may be found free in nature? **6**

gold / copper …6

(*d*) What is *electrolysis*? **2×3**

using electricity or an electric current …3

to bring about a chemical reaction or change …3

[example other than electrolysis of $PbBr_2$ ..3]

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

mass of an element (deposited at or liberated at an electrode) proportional to …3

the charge that flowed or passed …3

[electricity, current, voltage instead of charge (–1)]

(*e*) Lead(II) bromide ($PbBr_2$) is an ionic compound that has a low melting point. Figure 15 shows the electrolysis of molten lead(II) bromide using inert electrodes X and Y.

(i) Suggest a material suitable for the electrodes. **6**

graphite / carbon / platinum …6

(ii) How is the current conducted through the molten electrolyte? **3**

(movement of) ions …3

(iii) At which electrode does oxidation occur? **3**

anode / positive electrode / X / electrode on left …3

(iv) Write a balanced equation for the reaction that occurs at the cathode. **3**

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

(*f*) When a current of 5.00 A was passed through molten lead(II) bromide for *t* seconds, 4.14 g of lead was deposited.
Calculate

(i) the number of moles of lead produced <u>**2×3**</u>

M_r = 207 …3

$\frac{4.14}{207} = 0.02$ (moles) ...3

(ii) the number of electrons transferred to produce this lead <u>**3**</u>

$2 \times 0.02 \times 6.0221415 \times 10^{23} = 2.41 \times 10^{22}$ (electrons) [$2.4 \times 10^{22} – 2.41 \times 10^{22}$] ...3

(iii) the value of *t*. <u>**2×3**</u>

$0.04 \times 96485.3383 = 3859.41$C / $2.4 \times 10^{22} \times 1.602176 \times 10^{-19} = 3845.2$ C [3845.2 – 3860] ...3

$Q = It$ / $5t = 3859.41 \Rightarrow t = 772$ (s) /12 min 52 s ...3

[no calculation or ncorrect calculation...(–1)]

Question 11

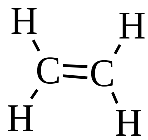
Ethene is a small <u>hydrocarbon</u> molecule and is the first member of the alkene <u>homologous series</u>.

(*a*) Explain the underlined terms. **<u>4×3</u>**

hydrocarbon is a compound containing carbon …3
and hydrogen only …3
[‘only ‘omitted …(–1)]

homologous series is a group of organic compounds ...3
with same chemical properties or same
functional group / differ by $–CH_2$ / have common method of preparation / can be represented by a common formula ...3

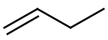
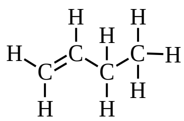
(*b*) Draw the structure of the ethene molecule. **<u>3</u>**



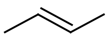
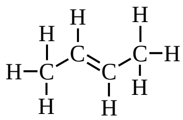
...3

Give the names and structural formulae of two members of the alkene family that have four carbon atoms. **<u>4×3</u>**

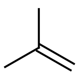
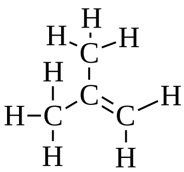
but-1-ene or 1-butene …3

$CH_2=CHCH_2CH_3$ or  or  …3

but-2-ene or 2-butene ...3

$CH_3CH=CHCH_3$ or  or  ...3

methyl propene …3

$CH_3C(CH_3)CH_2$ or  or  ...3

[any two correct names and corresponding structures]

(*c*) Describe, with the aid of a labelled diagram, an experiment to prepare ethene gas. **<u>4×3</u>**

ethanol and aluminium oxide or Al_2O_3 // ethanol and H_2SO_4 …3
test-tube on side, glass wool to hold ethanol // flask, air condenser …3
heat aluminium oxide with Bunsen // heat flask with Bunsen …3
collect ethene gas over water …3
[no labels …(–3)]

How could the gas be tested for unsaturation? **<u>2×3</u>**

(add to) bromine solution / (add to) bromine water // acidified potassium permanganate ($KMnO_4$) …3
red or brown or yellow to colourless // purple or pink to colourless /decolourised …3
[omit ‘acidified’…(–1)] [clear instead of colourless unacceptable]

(*d*) Name the reagent required, in each case, to convert ethene to

(i) ethane **<u>3</u>**

hydrogen gas or H_2 3

(ii) chloroethane **<u>3</u>**

hydrogen chloride or HCl ...3

[hydrochloric acid …(–1)]

(iii) 1,2-dichloroethane **<u>3</u>**

chlorine gas or Cl_2 ...3

(iv) ethanol **<u>3</u>**

water or H_2O ...3

What is the common type of reaction that occurs in each of these conversions? **<u>3</u>**

addition …3

(*e*) Ethene burns in air with a luminous flame. Write a balanced equation for the complete combustion of ethene. **<u>2×3</u>**

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

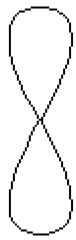
correct products …3

balanced …3

[incorrect equation but balanced...3]

Question 12
Answer any three parts.

Question 12(*a*)
What is an atomic orbital? **2×3**
region in space (in an atom) / region around the nucleus (of an atom) …3
where there is a high probability of finding an electron …3
['area' instead of 'region'…(–1)]

Sketch the shape of a *p*-orbital. **3**

…3

What is the maximum number of electrons that can occupy a single *p*-orbital? **3**
2 …3

What information about an electron in an atom is given by
(i) the first (principal) quantum number **3**
shell / main energy level / orbit (to which an electron belongs) ...3

(ii) the fourth quantum number? **3**
spin …3

What happens to an electron in an atom when it obtains energy? **4**
jumps or moves into a higher energy level /enters an excited state / escapes from the atom / emits light …4

Question 12(*b*)
Sulfuric acid (H_2SO_4) is a strong acid that is used in car batteries like that shown in Figure 16. The sulfuric acid is concentrated when the battery is fully charged. When the battery is 'flat' the sulfuric acid in the battery is very dilute.

Define *an acid* according to Brønsted-Lowry theory. **4**
proton donor …4

Distinguish between a *concentrated* solution and a *dilute* solution of an acid. **2×3**
concentrated solution has large quantity of acid in a (relatively) small amount or volume of water or solvent …3
dilute solution has a small quantity of the acid in a (relatively) large quantity or volume of water or solvent …3
[concentrated solution has large quantity of acid, dilute solution has small quantity of acid...3]
[concentrated solution has small quantity / volume of water,
dilute solution has large quantity / volume of water...3]

Distinguish between a *strong* acid and a *weak* acid. **2×3**
a strong acid is a good proton donor / fully dissociated …3
a weak acid is a poor proton donor / slightly or weakly or not fully dissociated …3
[partially dissociated...(−1)]

Calculate the pH of a 0.06 M solution of sulfuric acid **2×3**
$pH = -\log[H^+]$ / $pH = -\log[0.06]$ …3
$pH = -\log 0.12 = 0.92$ …3

Question 12(*c*)
The following balanced equation shows the reaction that occurs when ammonium nitrate (NH_4NO_3) decomposes when heated to form nitrogen(I) oxide (N_2O).

$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

Nitrogen(I) oxide gas is frequently used to anaesthetise patients during dental surgery and is sometimes known as 'laughing gas' because of the behaviour of many patients as they recover from its anaesthetic effects.

Would you expect nitrogen(I) oxide to be acidic, basic or neutral? Justify your answer. **2×2**
neutral …2
does not react with acids or bases / safe to give to patients …2

A cylinder of nitrogen(I) oxide for use in a dental surgery contained 2200 g of the gas.
Calculate
(i) the number of moles of nitrogen(I) oxide contained in the cylinder **2×3**
$M_r = 44$ ...3
$2200 \div 44 = 50$ (moles) ...3

(ii) the volume that this gas would occupy at s.t.p. **3**
$50 \times 22.4 = 1120$ litres / $50 \times 22400 = 1120000$ cm^3 ...3
[no unit or incorrect unit …(−1)]

(iii) the mass of ammonium nitrate that decomposed to produce this quantity of gas **2×3**
$M_r = 80$ ...3
$80 \times 50 = 4000$ (g) / 4 kg ...3

(iv) the number of water molecules formed in this reaction. **3**
$100 \times 6.0221415 \times 10^{23}$ C $= 6 \times 10^{25}$ (molecules) …3

Question 12(*d*)
Define heat of combustion. **3×2**
heat change or heat released or produced or evolved when one mole (of a substance) / …3
is burned in excess oxygen / completely burned …3
[heat involved…(−1)][excess omitted...(−1)]

Consider the following three heats of reaction.

$$2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)} \qquad \Delta H = -566.0 \text{ kJ}$$
$$CO_{(g)} + 2H_{2(g)} \rightarrow CH_3OH_{(l)} \qquad \Delta H = -128.1 \text{ kJ}$$
$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)} \qquad \Delta H = -571.6 \text{ kJ}$$

Use Hess's law and the heats of reaction above to calculate the heat change for the following reaction.

$$2CO_{2(g)} + 4H_2O_{(l)} \rightarrow 2CH_3OH_{(l)} + 3O_{2(g)}$$ **4×3**

$2CO_{2(g)} \rightarrow 2CO_{(g)} + O_{2(g)}$ $\quad \Delta H = 566.0$ kJ ...3
$2CO_{(g)} + 4H_{2(g)} \rightarrow 2CH_3OH_{(l)}$ $\quad \Delta H = -256.2$ kJ ...3
$4H_2O_{(l)} \rightarrow 4H_{2(g)} + 2O_{2(g)}$ $\quad \Delta H = 1143.2$ kJ ...3
$2CO_{2(g)} + 4H_2O_{(l)} \rightarrow 2CH_3OH_{(l)} + 3O_{2(g)}$ $\quad \Delta H = 1453$ kJ ...3

Hence find the heat of combustion of methanol (CH_3OH). **2×2**
reverse −1453.0 kJ ...2
divide by 2 −726.5 kJ mol^{-1} …2
[no unit or incorrect unit …(−1)]

Blank Page