# Coimisiún na Scrúduithe Stáit
State Examinations Commission

# Leaving Certificate 2013

# Marking Scheme

# Physics and Chemistry

# Higher Level

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

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

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

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

**Future Marking Schemes**

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

**General Guidelines**

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

**1.** In many instances only key words are given, 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.** 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.

**Question 1**
**Any eleven parts** **11×6**

**(*a*) State *Newton's third law of motion.*** **2×3**
for every action // for every force …3
there is a reaction // there is an equal and opposite force …3
[example of both action and reaction...3]

**(*b*) Distinguish between a vector and a scalar.** **5, 1**
vector has direction (and magnitude) …5
scalar does not have direction /has magnitude only …1
[reversed...3]

**(*c*) Define the unit of power, i.e. the *watt*.** **2×3**
one joule …3
per second …3
[energy used / work done per unit time / $P = VI$ / $\frac{work}{time}$ / $\frac{energy}{time}$ ...3]

**(*d*) Identify the wave phenomena shown at A and at B in Figure 1.** **2×3**
A: (constructive) interference …3
B: diffraction /diffraction and interference …3

**(*e*) Describe what happens in the *photoelectric effect*.** **2×3**
release of electrons from metal (surface) …3
when light or electromagnetic radiation of suitable frequency is incident on it …3
[any named metal...3]

**(*f*) What is a transverse wave?** **2×3**
vibration of wave /vibration of medium //direction of movement of wave …3
perpendicular to direction of energy transfer / perpendicular to direction of propagation (of wave) // perpendicular to direction of vibration of wave particles …3
[example of a transverse wave...3]
[correct idea of perpendicularity associated with a wave…3]

**(*g*) Calculate the energy of a photon of ultraviolet light that has a frequency of $1.2 \times 10^{15}$ Hz.** **2×3**
$E = hf$ …3
$E = 6.6 \times 10^{-34} \times 1.2 \times 10^{15} = 7.9(2) \times 10^{-19}$ (J) …3

**(*h*) State *Boyle's law*.** **2×3**
the pressure of a fixed mass of gas // $P \propto 1/V$/ $PV = k$ / $P_1V_1 = P_2V_2$ …3
is inversely proportional to its volume at constant temperature//at constant temperature, explain terms …3
[at constant temperature omitted (–1)]

**(*i*) What is a thermometric property? Give an example.** **2×3**
(property) that changes (measureably) with temperature …3
height/volume of liquid (in a column), volume of gas at constant pressure, pressure of 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

**(*j*) What is the purpose of the fuse in the plug shown in Figure 2?** **2×3**
safety / melts or 'blows' / stops flow of current …3
when current is too big …3

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

emf / current produced (in a conductor or coil) // $E = -N\frac{d\emptyset}{dt}$ / $E = -\frac{\mathrm{d}\emptyset}{\mathrm{d}t}$ / $E = \frac{d\emptyset}{dt}$ …3

when there is a change in magnetic flux // explain terms …3

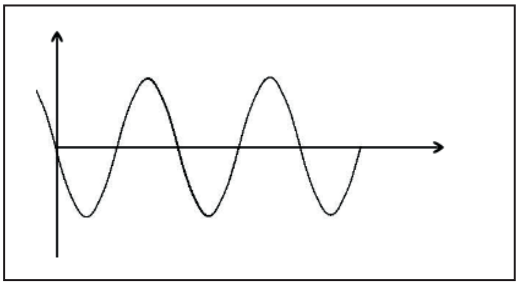
[cutting through lines of force……(–1)]

**(*l*) State the principle on which the operation of the moving coil galvanometer is based.** **2×3**

force on a current carrying conductor …3

in a magnetic field …3

**(*m*) Figure 3 represents an alternating current. Copy the diagram into your answerbook and label the axes.** **2×3**



time / s …3

voltage / current / V / A …3

**(*n*) What is meant by *radioactivity*?** **2×3**

(spontaneous) disintegration of (unstable) nuclei / (spontaneous) decay of (unstable) nuclei …3

with emission of particles or energy /emission of radiation …3

[‘atom’ instead of ‘nucleus’....(–1)]

**(*o*) Give two properties of a beta particle.** **2×3**

negatively charged or charge of minus one, electrons, high speed particles, moderately penetrating, moderately ionising, deflected in an electric field, deflected in a or magnetic field, negligible mass or very small mass or 1/1840 amu, speeds of 30 -70 % speed of light, etc.

any two… 2×3

**Question 2**

**(*a*) Define (i) momentum,** **2×3**

product of mass //$m$ or $m\times$ …3

and velocity // $v$, explain $m$ and $v$ …3

[omit to explain $m$, $v$ (–1)]

**(ii) potential energy.** **6**

energy due to position or mechanical condition // $mgh$ //stored energy ...6

[$m$, $g$, $h$ not explained....(–1)]

**(*b*) State the law of conservation of energy.** **2×3**

total energy is conserved /energy cannot be created or destroyed …3

but energy can be converted from one form into another …3

**(*c*) List the energy conversions that occur**

**(i) while a hailstone is falling** **3**

potential energy to kinetic energy …3

[potential (energy) only or kinetic (energy) only....(–1)]

**(ii) when a hailstone strikes the ground** **3**

kinetic to heat / sound / vibrational (energy) …3

[kinetic only or heat only or sound only or vibrational only...(–1)]

**(iii) as a hailstone bounces up from the ground.** **3**

kinetic to potential …3

[kinetic only or potential only....(–1)]

**(*d*) Describe, with the aid of a labelled diagram, a laboratory experiment to measure velocity** **9, 3**

labelled diagram with trolley on sloped track or on a smooth frictionless horizontal track, e.g. air track
moving at constant velocity mentioned or shown in ticker tape diagram or otherwise
timing using ticker tape timer, light gates, Fletcher's trolley, etc gives $t$
measure length of ten spaces on tape $s$ /measure length of card $s$ ..

velocity = $\frac{s}{t}$ / velocity = $\frac{s}{0.2}$ / velocity = $\frac{distance}{time}$/ datalogger or datalogger and computer or computer measure velocity

[no diagram (−3), no labels (–1 )] [first correct…9,second correct…3]

**(*e*) Calculate**

**(i) the change in momentum when a large raindrop of mass 0.065 g travelling vertically with a velocity of 9 m s$^{-1}$ strikes the ground and comes to rest** **3, 6**

$m(u – v) = mu – mv$ …3

[allow $mv – mu$]

$0.065(9 – 0) = 0.585$ g m s$^{-1}$ or 0.000585 kg m s$^{-1}$ = $5.85 \times 10^{-4}$ kg m s$^{-1}$ …6

[no unit or incorrect unit (–1)]

**(ii) the change in momentum when a hailstone of mass 0.065 g travelling vertically with a velocity of 12 m s$^{-1}$ strikes the ground and rebounds with an initial upwards velocity of 2 m s$^{-1}$** **6**

$m(u – v) = 0.065(12 – –2) = 0.78 + 0.13 = 0.91$ g m s$^{-1}$ or 0.00091 kg m s$^{-1}$ = $9.1 \times 10^{-4}$ kg m s$^{-1}$ …6

[0.065(12-2) = 0.65 g m s$^{-1}$ or 0.00065 kg m s$^{-1}$ = $6.5 \times 10^{-4}$ kg m s$^{-1}$ …3]

[no unit or incorrect unit (–1)]

**(iii) the force exerted on the ground by the hailstone if it remains in contact with the ground for 0.08 s.** **2×3**

$v = u + at \,/ a = (\frac{v-u}{t})$

$a = \frac{[2-(-12)]}{0.08}$ =175 ms$^{-2}$ …3

[no unit or incorrect unit (–1)]

[allow positive or negative sign]

$F = ma$ = 0.065 × 175 = 0.011375 N = 11.375 g m s$^{-2}$ …3

[no unit or incorrect unit (–1)]

[allow positive or negative sign]

**or**

F= $\frac{(mv-mu)}{t}$ ...3

F= $\frac{[0.00013-(-0.00078)]}{0.08}$ =0.011375N=11.375 g m s$^{-2}$ ...3

**(iv) the maximum height reached by the hailstone after the bounce.** **2, 1**

$v^2 = u^2 + 2as$ / 0 = 4 – (2× 9.8 × $s$) / $\frac{1}{2}mv^2 = mgh$ / $\frac{1}{2}mv^2 = Fs$ …2

$s$ = 0.2(04) m …1

[no unit or incorrect unit (–1)]

**Suggest a reason why hailstones, striking bare skin, hurt more than raindrops do.** **3**

rate of change of momentum smaller / smaller force exerted / hailstones have greater velocity than raindrops or raindrops have smaller velocity than hailstones/hailstone is hard/raindrop is soft …3

**Question 3**

**(*a*) State the laws of reflection of light.** <u>**2×3**</u>

the incident ray, the reflected ray and the normal all lie in the same plane …3
[refraction instead of reflection (– 1)]

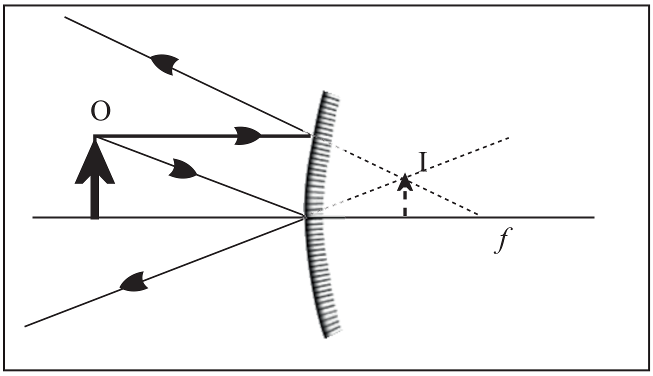
angle of incidence is equal to the angle of reflection / $i = r$ …3
[refraction instead of reflection (– 1)] [no need to explain $i$, $r$ etc ]

**(*b*) Distinguish between a real image and a virtual image, in terms of light rays.** <u>**6**</u>

real image formed by (actual) intersection of light rays / virtual image formed by apparent intersection of light rays …6
[real image inverted or can be formed on a screen / virtual image upright or cannot be formed on a screen …3]

**(*c*) Draw a ray diagram to show the formation of an image of an object by a convex mirror.** <u>**3×3**</u>

object shown in front of convex mirror with at least one label …3
one ray reflected correctly …3
ray(s) projected back to form upright diminished image behind mirror …3




**(*d*) An experiment was carried out to measure the focal length of a convex mirror. A tall search pin was used to locate each image.** <u>**9, 9, 1, 1, 1**</u>

**(i) Sketch the arrangement of the apparatus.**
convex mirror / object in front of mirror / search pin behind mirror

**(ii) Explain why the images could not be located using a screen.**
images virtual / only real images can be formed on a screen / images behind mirror

**(iii) How was the tall search pin used to find the image positions?**
find image by no parallax / move search pin until it coincides with image pin

**(iv) What measurements were made in the experiment?**
measure object distance and image distance // measure $u$ and $v$ (if marked on diagram)

**(v) How were these measurements used to determine the focal length of the mirror?**
use formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ / graph of $\frac{1}{u}$ versus $\frac{1}{v}$
[find image on screen …6 max]

**(vi) Mention one precaution taken to ensure an accurate result.**
avoid errors of parallax reading scales, repeat with many image positions, /measure distances to pole or centre of mirror ,etc

[$9 \times 2$ for first two correct points, then $3 \times 1$]

**(*e*) Give one advantage and one disadvantage of using a convex mirror instead of a plane mirror as the exterior door mirror on a car.** **2×3**

advantage: wide field of view /,always erect …3

disadvantage: image diminished, image distance reduced compared to actual distance …3

**(*f*) A car door mirror has a focal length of 1.5 m. An ambulance is 21 m from the mirror. An image of the ambulance is formed by the mirror.**

**Calculate**

**(i) the image distance** **4×3**

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}\ /\ -\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$$ ...3

$$-\frac{1}{1.5}=\frac{1}{21}+\frac{1}{v}$$ …3

$$\frac{1}{v}=-\frac{1}{1.5}-\frac{1}{21}$$ ...3

$$v=(-)\ \frac{7}{5}=(-)1.4\text{ m}$$ …3

[no unit or incorrect unit (–1)]

[if mirror treated as concave ($v$ = 1.62 m) max... 9]

**(ii) the magnification.** **2×3**

$$m=\frac{v}{u}$$ …3

$$(m)=\frac{1.4}{21}=\frac{1}{15}=\ 0.06667\ /\ (m)=\frac{1.62}{21}=0.077$$ …3

**Question 4**

**(*a*) The kinetic theory of gases explains the properties of an *ideal gas* in terms of the behaviour of its molecules. *Brownian motion* provides evidence for the kinetic theory.**

**State two of the assumptions of the kinetic theory of gases.** <u>**2×3**</u>

large number of particles or molecules, particles or molecules have negligible volume, in constant motion, in rapid motion, in random motion, in straight line motion, collide with one another, collide with walls of the container, collisions elastic or involve neither loss nor gain of energy, collision times of short duration, no interaction between particles or molecules except during collisions, etc

any two …2×3

**Define the ideal gas.** <u>**2×3**</u>

an ideal gas obeys gas laws or Boyle's law or satisfies kinetic theory assumptions …3

at all temperatures and pressures …3

[temperature or pressure omitted (–1)]

**State two ways in which the behaviour of a real gas differs from the behaviour of the ideal gas.** <u>**2×3**</u>

a real gas obeys gas laws or Boyle's law or satisfies kinetic theory assumptions (except at high pressure and low temperatures), molecules of a real gas have volume but particles or molecules of an ideal gas are point masses or have no/negligible volume , there are attractive forces between the molecules of a real gas but there are no forces between the particles or molecules of a real gas, real gas can condense into a liquid

any two …2×3

**Describe how you would demonstrate Brownian motion.** <u>**6, 3**</u>

arrangement of smoke in air cell / pollen in water, etc

view with microscope

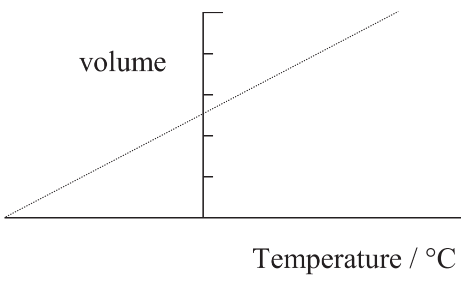
rapid, continuous, random, straight line, zig-zag / visible smoke particles colliding with invisible air particles

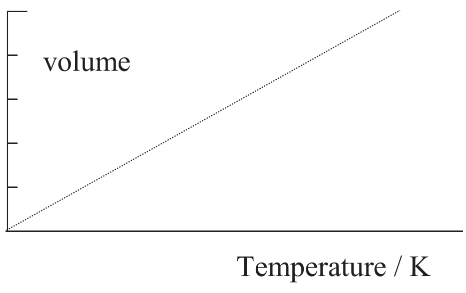
[straight line and zig-zag may be obtained from a diagram]

[first correct point …6, second correct point…3]

**(*b*) In 1787 Jacques Charles investigated the relationship between the volume and the temperature of a fixed mass of gas at constant pressure.**

**Sketch a labelled graph to show the relationship established by Charles.** <u>**3×3**</u>




axis labelled volume …3

axis labelled temperature …3

straight line through positive y-axis when temperature is in Celsius, straight line through origin when temperature in kelvin …3

**How is the concept of absolute zero related to Charles law?** **2×3**

temperature corresponding …3

to zero volume …3

[lowest temperature theoretically possible ...3]

**(c) A weather balloon like that shown in Figure 5, carrying a small instrument package that transmitted weather data, was filled with hydrogen gas. At ground level when the temperature was 5.0 °C, the balloon had a volume of 4.2 $m^3$. At night, when the temperature had dropped, the volume was 3.9 $m^3$. Assuming that the atmospheric pressure remained constant at $1 \times 10^5$ N $m^{-2}$, use Charles' law to deduce the night-time temperature at ground level.** **3×3**

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ …3

$$\frac{4.2}{298} = \frac{3.9}{T_2}$$ …3

$T_2$ = 258.14 K or –14.86 °C …3

[Use of Celsius instead of Kelvin....(–3)]

**Calculate the number of moles of hydrogen gas in the balloon** **3×3**

$PV = nRT$ …3

$1 \times 10^5 \times 4.2 = n \times 8.31 \times 278$ / $1 \times 10^5 \times 3.9 = n \times 8.31 \times 258.14$ ...3

n = 181.8 ...3

[any incorrect multiple of 181.8 (–1)]

[no substitution for $R$ (–3)]

**When the balloon was released it ascended, expanding as it rose, to a height of about 30 km where it had a volume of 464 $m^3$. The temperature reading transmitted at this height was 230.7 K.**

**Calculate the pressure of the atmosphere at this height.** **2×3**

$PV = nRT$

$P \times 464 = 181.8 \times 8.31 \times 230.7$ …3

($P$ =) 751.15 N $m^{-2}$ …3

[any incorrect multiple of 751.15 (–1)]

[no substitution for $R$ (–3)]

**or**

$$P_1V_1 = P_2V_2 \,/\, \frac{1\times10^5\times4.2}{278} = \frac{P_2\times464}{230.7} \,/\, \frac{1\times10^5\times3.9}{258.14} = \frac{P_2\times464}{230.7}$$ …3

$P_2$ = 751.15 N $m^{-2}$ …3

**Question 5**

**(*a*) State *Ohm's law.*** <u>2×3</u>

current is proportional to or $I \propto$ // potential difference is proportional to or $V \propto$ // V = …3

potential difference or $V$ at constant temperature // current or $I$ at constant temperature // $IR$ at constant temp. …3

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

**Define *resistance*.** <u>2×3</u>

ratio of potential difference // $V/I$ …3

to current (through a conductor) // explain symbols …3

[opposition to flow of current/electrons...3]

**Define *the ampere,* SI unit of current.** <u>3×3</u>

two <u>infinitely</u> long <u>parallel</u> conductors …3

one metre apart in a <u>vacuum</u> ...3

exert a force of $2 \times 10^{-7}$ <u>newton per metre</u> or $2 \times 10^{-7}$ <u>N m$^{-1}$</u> …3

[every underlined term omitted (–1)]

**(*b*) A student measured the temperature rise $\Delta\theta$ of a fixed mass of water in a certain time for a number of different currents *I*, using a heating coil immersed in the water.**

**Draw a labelled diagram of an apparatus that could have been used.** <u>3×3</u>

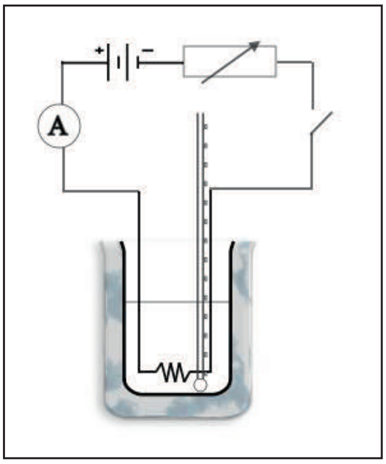
circuit showing power supply, (variable resistor,) …3

ammeter …3

thermometer …3

[diagram without labelling (–3)]

[accept A for ammeter as a label]




The following data were recorded.

| $I$/A | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 |
|---|---|---|---|---|---|---|---|
| $\Delta\theta$/K | 1.0 | 4.1 | 8.8 | 15.8 | 24.4 | 36.1 | 50.0 |

**Use the data to draw a suitable graph to show the relationship between the rise in temperature of the water and the current.** <u>5×3</u>

axes labelled $\Delta\theta$ and $I^2$ or temperature change and current squared …3

suitable scales marked °C (or K) and $A^2$ …3

six points plotted accurately …3

suitable straight line …3

through the origin …3

[allow maximum 9 for $\Delta\theta$ *and* I as follows: 3 marks for axes labelled $\Delta\theta$ and $I$ or temperature change and current, 3 for units °C (or K) and A, 3 for six points plotted accurately]

[No graph paper...(–3)]

**(*c*) In an 'instant' electric shower, the temperature of a fixed mass of water is raised over a short period of time.**

**Calculate the current in the heating coil of an 8.5 kW electric shower that is connected to the mains supply of 230 V when it is used at full power.** **2×3**

$P = VI$ / $8500 = 230I$ …3
$I$ = 36.96 A …3
[no unit or incorrect unit (–1)]
[any incorrect multiple of 36.96(–1)]

**Hence calculate the resistance of the heaing coil.** **2×3**
$P = RI^2$ / $8500 = R\,(36.96)$ // $V = IR$ / $230 = 36.96R$ …3
R = 6.22 Ω ...3

**The temperature rise of the water when the shower is operating at full power is 30 °C.**
**Deduce the temperature rise, assuming the same flow rate of water, when the shower is used at half power.** **3**
$\Delta\theta \propto I^2 \propto P \Rightarrow$ temperature rise 15 °C …3
**or**
$\Delta\theta \propto I^2 \propto P^2 \Rightarrow$ temperature rise 7.5 °C …3

**State two effects of an electric current, other than heating.** **5, 1**
chemical
magnetic
[first correct gets 5 marks, second 1 mark]

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

**Question 6(*a*)**

**Define weight.** **3**
product of mass and acceleration due to gravity / $mg$ / force due to gravity …3
[omit to explain $m$ and $g$ (–1)]

**What is the weight of a 0.2 kg apple?** **3**
$W = mg = 0.2 \times 9.8 = 1.96$ N …3
[no unit or incorrect unit (–1)]

**Describe an experiment to measure to acceleration due to gravity, *g*.** **6, 3, 3, 3**
string, bob // ball, trapdoor // any free falling object
point of suspension arrangement correctly described or drawn // electromagnet, timer // light gates
pendulum length, $l$ // distance from electromagnet to trapdoor, $s$ // distance between light gates, $s$
time for $n$ oscillations // time for fall, $t$ // $t_1$ and $t_2$
use formula $T = 2\pi\sqrt{\frac{l}{g}}$ / find slope from graph of $l$ versus $T^2$ // use formula $s = ½gt^2$ / find slope from graph of $s$ versus $t^2$ // $v^2 = u^2 + 2gs$
[first correct …6, then 3×3]

**State *Newton's law of universal gravitation.*** **2×3**
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**

$F \propto \frac{m_1 m_2}{d^2}$ / $F = \frac{G m_1 m_2}{d^2}$ …3
terms explained ..3
[square omitted (–3)][sum instead of product of masses (–3)][omit to explain $F$, $G$, $m_1$, $m_2$, $d$ (–1) each]

**Calculate the gravitational force between the 0.2 kg apple and the earth. The mass of the earth is $6.0 \times 10^{24}$ kg and its radius as $6.4 \times 10^6$ m.** **2×3**
$(F =)\frac{G m_1 m_2}{d^2} = \frac{6.67\times10^{-11}\times0.2\times6.0\times10^{24}}{(6.4\times10^6)^2}$ / ($F$) = $mg$ = 0.2 × 9.8 …3
($F$ =) 1.954 N **or** 1.96 N …3
[no unit or incorrect unit (–1)]

**Question 6(*b*)**

**Define (i) critical angle** <u>**2×3**</u>

angle of incidence corresponding to …3

an angle of refraction of 90° ….3

**(ii) total internal reflection** <u>**2×3**</u>

if light is incident on the boundary between a denser medium and a rarer medium and exceeds the critical angle / if angle of incidence exceeds the critical angle ...3

(all) the light is reflected at the boundary ...3

[occurs when angle of refraction is greater than 90° (–1)]

[diagram maximum …3]

**Two rays of light labelled A and B, travelling through air, enter a semi-circular block of glass as shown in Figure 6. The path of ray A in the glass and as it emerges into air is also shown.**

**Calculate**

**(i) the refractive index of the glass** <u>**3**</u>

$n = \frac{\sin i}{\sin r} = \frac{\sin 37}{\sin 24} = 1.48$ …3

**(ii) the critical angle for the glass** <u>**3×3**</u>

$n = \frac{1}{\sin c}$ / $\sin c = \frac{1}{n} = \frac{1}{1.48}$ …3

$\sin c = 0.6757$ …3

$c = 42.51°$ …3

**(iii) the speed of light in the glass.** <u>**2×3**</u>

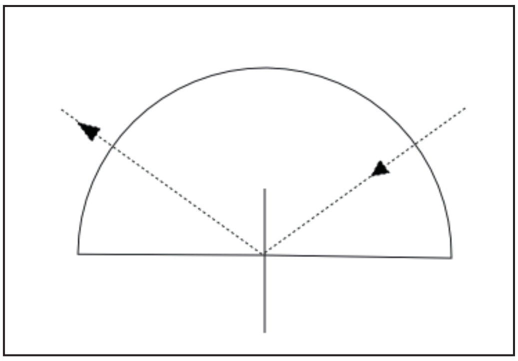
$n = \frac{c_1}{c_2}$ / $\frac{3 \times 10^8}{c_2} = 1.48$ …3

$c_2 = 2 \times 10^8 \text{ m s}^{-1}$ …3

[no unit or incorrect unit (–1)]

**Copy the diagram into your answer book and complete the pathway followed by ray B showing clearly where ray B emerges from the glass block.** <u>**3**</u>

beam totally internally reflected and emerges radially …3



**Question 6 (*c*)**

**Define capacitance.** <u>2×3</u>

ratio of charge // $Q/V$ …3

to potential //explain symbols …3

[ability to store charge.....3]

**Describe an experiment to show how the capacitance of a parallel-plate capacitor depends on the common area of the plates.** <u>3×3</u>

parallel plate capacitor, electroscope …3

change common area, observe effect on electroscope leaf divergence ..3

divergence increases when common area is least hence capacitance increases when common area is greatest /when common area increases capacitance increases ...3

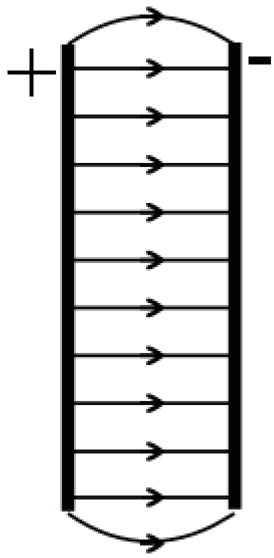
**The switch in the circuit shown in Figure 7 was initially in position B. The switch was moved from position B to position A, connecting the 9 μF parallel-plate capacitor to the 12 V battery. What charge was stored in the capacitor?** <u>2×3</u>

$C = \frac{Q}{V}$ / $Q = CV$ …3

$Q = 9 \times 12 = 108\ \mu C = 1.08 \times 10^{-4}$ C …3

[no unit or incorrect unit (–1)]

**Draw the electric field pattern around a charged capacitor.** <u>2×3</u>




parallel lines between plates …3

arrows showing direction of field from positive to negative plate …3

**When the switch was then moved to position C, the bulb glowed briefly. Explain.** <u>2×3</u>

capacitor discharges // energy stored in capacitor // current flows (from capacitor) …3

quickly // used to light bulb // bulb lights …3

**Question 6 (*d*)**

**The sun and other stars obtain their energy from nuclear fusion reactions.**
**Distinguish between nuclear fission reactions and nuclear fusion reactions.** **<u>2×3</u>**
fission is splitting of a large nucleus …3
into (two) nuclei …3
**<u>6</u>**
fusion is the joining /combining of two nuclei ...6

[if 'atom' used instead of 'nucleus deduct 3 marks only once]
[if 'two omitted in definition of fusion (–1)]

**The following fusion reaction occurs in the sun.**

$$^{1}_{1}\mathbf{H} + {}^{2}_{1}\mathbf{H} \rightarrow {}^{3}_{2}\mathbf{He} + \textbf{energy}$$

**Using the relevant data listed on page 83 of the *Formulae and Tables* booklet, calculate the energy released by this reaction when one helium–3 nucleus is produced.** **<u>5×3</u>**
initial mass = (1.007825 + 2.014102) = 3.021927 …3
mass lost = (3.021927 – 3.016029) = 0.005898 …3
$E = mc^2$ ...3
$= 0.005898 \times (3\times 10^8)^2 = 5.3082 \times 10^{14}$ ...3
$5.3082 \times 10^{14} \times 1.66 \times 10^{-27} = 8.81 \times 10^{-13}$ (J) ...3

**Controlled nuclear fusion has not yet been achieved.**
**Give one potential advantage that nuclear fusion would have over nuclear fission for energy production.** **<u>3</u>**
raw materials plentiful, waste disposal problems minimal, lower radiation levels than in fission, less harmful, safer
any one...3

**Give an example of an application of an uncontrolled nuclear fusion reaction that has already been developed on earth.** **<u>3</u>**
H-bomb / hydrogen bomb …3

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

(*a*) **Identify the metal associated with (i) a yellow colour, (ii) a lilac colour, when metal salts are heated strongly in a Bunsen flame.** **5, 1**
(i) sodium
(ii) potassium
[reversed …3] [first correct…5,second correct…1]

(*b*) **Define the *relative atomic mass* of an element.** **2×3**
average mass of (the mass numbers of) all the isotopes // mass of atom relative to …3
taking their natural abundances into account // 1/12$^{th}$ carbon-12 isotope …3

(*c*) **What information about an electron in an atom is given by**
**(i) the principal quantum number, (ii) the fourth quantum number?** **5, 1**
(i) (main) energy level (occupied by the electron) / shell (occupied by the electron)
(ii) spin (of electron in an orbital)
[first correct gets 5 marks, second 1 mark]

(*d*) **Give a reason why (i) the first ionisation energy values show a general increase, (ii) atomic radii decrease, across the periods in the periodic table of the elements.** **5, 1**
(i) decreasing atomic radius / increasing nuclear charge / increasing number of protons
(ii) increasing nuclear charge / increasing number of protons [first correct…5,second correct…1]

(*e*) **Explain, in terms of bonding, how metals can conduct electricity.** **5, 1**
electrons free to move …5
through positively charged ions …1

(*f*) **Select from the following the molecules that have a dipole moment.**
**$BF_3$ $CO_2$ $H_2O$ $NH_3$ $BeH_2$ $CH_4$** **5, 1**
$NH_3$
$H_2O$
[first correct gets 5 marks, second 1 mark]

(*g*) **The toxic chemical stibnite (antimony sulphide, $Sb_2S_3$) was used as an eye cosmetic in ancient times as shown in Figure 8. Calculate the percentage by mass of the element antimony in stibnite.**
[**S** = 32; **Sb** = 122] **2×3**
($M_r$) = 340 …3
$\frac{244}{340} \times 100 = 71.76$ % (72%) …3

(*h*) **What is meant by the *valency* of an element?** **2×3**
number of electrons (an atom of an element) // number of atoms of hydrogen …3
gives, takes or shares (when bonding) // with which an atom of the element combines or bonds …3
[charge on atom/ion...3]
[number of bonds formed...5]
[gives, takes or shares omitted (–1)]
[to achieve noble gas configuration or full outer shell when bonding (–1)]

**(*i*) Identify (i) the conjugate acid of $H_2PO_4^-$ (ii) the conjugate base of HF.** <u>2×3</u>

(i) **$H_3PO_4$** …3

(ii) **$F^-$** …3

[charge incorrect or no charge (–1)]

**(*j*) Give an example of (i) a basic oxide, (ii) an amphoteric oxide.** <u>5, 1</u>

(i) CaO, MgO, $Na_2O$, CuO, $Cu_2O$, FeO any basic oxide named or as a formula

(ii) ZnO / $Al_2O_3$ / $H_2O$

[first correct…5, second correct…1]

**(*k*) Define *heat of solution*.** <u>2×3</u>

heat change when one mole / heat involved when one mole …3

dissolves in excess solvent …3

[heat evolved (–1)]

[in excess water (–1)]

**(*l*) In connecting a Liebig condenser to a cold water tap, which nozzle A or B, as shown in Figure 9, should be used?** <u>6</u>

water in at lower nozzle / water in at A …6

**(*m*) What is a *functional group* in organic chemistry?** <u>2×3</u>

atom, group of atoms, type of bond …3

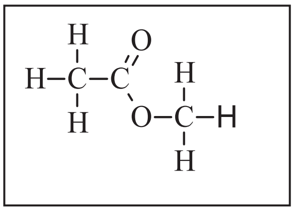
that gives an (organic compound) characteristic (chemical) properties …3

[example of functional group and relevant homologous series ...3]

**(*n*) Why is ultraviolet light essential if methane and chlorine are to react?** <u>6</u>

to break bond in chlorine /source of energy /to create free radicals ...6

**(*o*) Draw the molecular structure of methyl ethanoate.** <u>6</u>



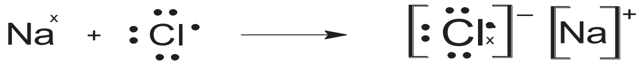
[$CH_3COOCH_3$ …3]

[hydrogen atoms need not be explicitly shown but carbon atoms must]

**Question 8**

**Substances, whether solid, liquid or gaseous, are composed of particles which may be ions, atoms or molecules.**

**(*a*) Figure 10 shows crystals of table salt, or sodium chloride, which is an ionic compound. Draw a dot and cross diagram to show how a sodium atom and a chlorine atom react to form sodium chloride.** <u>**4×3**</u>



sodium atom with one electron in outer shell …3
chlorine atom with seven outer electrons …3
monopositive sodium ion formed …3
negative chloride ion formed …3

**Describe the arrangement of ions within a crystal of sodium chloride.** <u>**3×3**</u>
each sodium ion is surrounded by six chloride ions …3
each chloride ion is surrounded by six sodium ions …3
cubic lattice formed / cubic arrangement / repeating structure/unit cell …3
[one of first two points may be clear from a diagram]
[one sodium...(–3)]

**(*b*) Use electronegativity values to predict the type of bonding that occurs in a water molecule.** <u>**6**</u>
3.44 (O) – 2.20 (H) = 1.24< 1.7 $\Rightarrow$ polar covalent …6
[omit polar (–1) or omit covalent (–1)]

**Use electron pair repulsion theory to predict the shape of a water molecule.** <u>**3**</u>
v-shaped (planar) (may be drawn) …3

**State the bond angle in the water molecule.** <u>**3**</u>
bond angle 104.5° / 104° …3

**Name the type of bonding that holds water molecules together in ice and that is broken when ice melts as shown in Figure 11.** <u>**3**</u>
hydrogen bonds / dipole-dipole forces …3

**Explain how this type of bond between water molecules is formed.** <u>**2×3**</u>
(partially) positively charged hydrogen (atom) in one molecule and (partially) negatively charged oxygen (atom) in neighbouring molecule …3
are attracted to each other …3
[allow 3 for hydrogen bonded to a small electronegative atom such as oxygen]

**(*c*) Explain**

**(i) why sodium chloride crystals are water soluble** <u>**5, 1**</u>
(sodium chloride crystals have) ionic (bonding) ...5
water molecules attracted to ions …1
[like dissolves like …3]

**(ii) the conduction of electricity by aqueous sodium chloride solution.** <u>**2×3**</u>
ions …3
free to move (when dissolved) …3

**(*d*) A crystal of diamond, the hardest known substance, is shown in Figure 12.**

**Name the category of crystal to which diamond belongs.** <u>**3**</u>
atomic / macromolecular / covalent …3

**What particles occupy the lattice points in a diamond?** <u>**3**</u>
(carbon) atoms …3

**Explain the hardness of diamond.** <u>**2×3**</u>
strong / four // each (carbon) atom bonded to four others …3
covalent bonds (holding each atom in place)// tetrahedrally …3

**Question 9**

**(*a*) Define an acid in terms of Brønsted-Lowry theory.** <u>3</u>

proton donor …3

[produces $H^+$ ions (–1)]

**Distinguish between a strong acid and a weak acid in terms of Brønsted-Lowry theory.** <u>2×3</u>

strong acid is a good proton donor …3

[fully dissociated (–1)]

weak acid is a poor proton donor …3

[slightly dissociated (–1), do not accept not fully dissociated]

**Give an example of a weak acid.** <u>3</u>

ethanoic acid, acetic acid, phosphoric acid, citric acid , vinegar, methyl orange, etc

any correct example …3

**(*b*) Define pH.** <u>3×3</u>

(pH = ) $-\log_{10}[H^+]$ …3

**Calculate the pH of a solution of**

**(i) 0.1 M HCl**

(pH = ) $-\log_{10}[H^+] = -\log_{10}[0.1] = 1(.0)$ …3

**(ii) 0.1 M $H_2SO_4$**

(pH = ) $-\log_{10}[H^+] = -\log_{10}[0.2] = 0.7$ …3

**A student titrated an acidic solution of *approximate* concentration 0.1 M and known to be *either* HCl *or* $H_2SO_4$ against 25.0 $cm^3$ portions of a standard sodium carbonate solution that had a concentration of exactly 0.05 M. The two possible titration reactions are as follows.**

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

$$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2$$

**(*c*) Name one indicator suitable for both of these titrations.** <u>3</u>

methyl orange …3

**Justify your choice of indicator.** <u>3</u>

strong acid titration / the colour change pH range of methyl orange matches the change in pH at the end point of this titration …3

**State the colour change observed at the end point.** <u>2×3</u>

yellow / orange / pink …3

red / pink/ peach …3

[colours reversed …3] [pink to pink …3]

**(*d*) Describe the correct procedure for rinsing, filling and emptying a pipette during the titration.** <u>4×3</u>

rinse with deionised water …3

rinse with the sodium hydrogen carbonate solution / rinse with the solution it will contain …3

use pipette filler …3

fill to zero mark / fill above zero and release …3

bottom of meniscus on the mark ….3

release liquid …3

allow time to drain …3

do not dislodge or shake out or blow out the last drop (inside) …3

touch tip of pipette gently against wall of conical flask to dislodge any outside drop …3

any four …4×3

**($e$) One rough and two accurate titrations were carried out and the following volumes of acidic solution were recorded: 24.9 cm$^3$, 24.6 cm$^3$ and 24.5 cm$^3$.**

**Determine, by calculation, whether the acid used was HCl or $H_2SO_4$.**

**Calculate, correct to three significant figures, the concentration of the acid in terms of (i) moles per litre, (ii) grams per litre.** **6×3**

$\frac{V_1M_1}{n_1} = \frac{V_2M_2}{n_2}$ / (volume$_1$ × molarity$_1$ × proticity$_2$) = (volume$_2$ × molarity$_2$ × proticity$_1$) …3

$$\frac{25\times 0.05}{1} = \frac{24.55\times 0.1}{n}$$ ...3

$$\frac{25\times 0.05}{1} = \frac{24.55\times M_2}{2}$$

$\Rightarrow n = 1.96$, indicates hydrochloric acid …3
[incorrect acid volume used ......(–1)]

**or**

volume of acid approximately equal to volume of base and concentration of acid is approximately double the base indicates monoprotic acid ...6
therefore hydrochloric acid …3
[correct acid without deduction shown...6]
[where error in deduction of acid (–3)]

$$\frac{25\times 0.05}{1} = \frac{24.55\times M_2}{2} \Rightarrow M_2$$
= 0.102 (M) …3

($M_r$) = 36.5/ 36.45 ...3
0.102 × 36.5 = 3.72 (g/L) / .102 × 36.45 = 3.72 (g/L) …3

[where 3 significant figures not given (–1)]

**($g$) How could the student have measured accurately the pH of the acid to confirm the identity of the acid?** **3**
pH meter/ universal indicator / pH sensor and datalogger …3

**Question 10**

**(*a*) Arrange the following metals in order of *decreasing* reactivity according to the electrochemical series.**

**silver iron aluminium zinc sodium** <u>**6**</u>

sodium, aluminium, zinc, iron, silver …6
[reversed …3, sodium first, silver last …3]

**Which of these metals may be found free in nature?** <u>**3**</u>
silver …3

**(*b*) What do the electron configurations of the transition metals have in common?** <u>**2×3**</u>
highest energy electron is /outermost electron is // forms an ion …3
in a partially filled d subshell // with a partially filled d subshell …3

**Which of the metals listed above are transition metals?** <u>**5, 1**</u>
iron
silver
[first correct…5,second correct…1 (cancelling applies for 3 or 4 metals)]

**List two properties that are common to transition metals.** <u>**2×3**</u>
coloured compounds, good catalysts, variable valency any two …2×3

**(*c*) Explain why iron corrodes more rapidly than aluminium.** <u>**3**</u>
aluminium oxide forms (impermeable) layer on aluminium surface/
a layer of aluminium oxide prevents further corrosion of the aluminium ...3

**How does galvanising with zinc protect iron from corrosion?** <u>**9**</u>
zinc prevents air and/or water making contact with iron/
zinc corrodes more easily than iron/ zinc sacrificial anode / zinc higher up electrochemical series / zinc more reactive any one...9

**(*d*) Write a balanced chemical equation for the reaction between sodium and water.** <u>**2×3**</u>
$Na + H_2O \rightarrow NaOH + ½H_2$ / $2Na + 2H_2O \rightarrow 2NaOH + H_2$
one product correct …3
balanced …3

**(*e*) Give two observations made when a zinc rod and a copper rod are dipped into sulfuric acid solution and joined as shown in Figure 13.** <u>**2×3**</u>
zinc dissolves, zinc reacts with sulphuric acid, bubbles of gas appear at copper, current flows, temperature rises.
any two …2×3

**Give a reason for one of these observations.** <u>**3**</u>
zinc above copper on electrochemical series / zinc being oxidised / simple cell / heating effect of electric current/ zinc above hydrogen in the electrochemical series …3

**(*f*) Define**
**(i) oxidation** <u>**3**</u>
loss of electrons …3

**(ii) reduction, in terms of electron transfer.** <u>**3**</u>
gain of electrons …3
[reversed...3]

**Identify the reducing agent in each of the following reactions that involve silver.**

$$2Ag + S \rightarrow Ag_2S$$

$$3Ag_2S + 2Al \rightarrow 6\,Ag + Al_2S_3$$

**2×3**

First: Ag …3

Second: Al ….3

**Question 11**

**(*a*) What is a homologous series of organic compounds?** <u>**2×3**</u>

(homologous series) is a group (of organic compounds )with
same chemical properties or same functional group / gradation in physical properties / differ by $CH_2$ / have common method of preparation any two …2×3

**(*b*) What is a hydrocarbon?** **2×<u>3</u>**

(compound) containing carbon and hydrogen …3
only ...3

**Explain the term *unsaturated hydrocarbon*.** <u>**2×3**</u>

unsaturated compounds have at least one double or triple bond …3
between a pair of carbon atoms …3
[example showing bonding between carbons...3]

**(*c*) Draw the structure of the ethyne molecule belongs.** <u>**3**</u>

H-C ≡ C-H …3

**Name the homologous series to which ethyne belongs.** <u>**3**</u>

alkynes …3

**The arrangement shown in Figure 14 is used in the preparation of the unsaturated hydrocarbon ethyne from liquid A and solid B.**

**(*d*) Identify liquid A and solid B and write a balanced equation for the reaction to prepare ethyne.** <u>**2×3, 6**</u>

A: water …3
B: calcium carbide / calcium dicarbide / $CaC_2$ …3

$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$ …6
[$Ca(OH)_2$ …3, balanced ..3]

**(*e*) Describe the flame observed when a test tube of ethyne is burned in air.** <u>**2×3**</u>

luminous / bright /yellow …3
smoky …3

**(*f*) Describe a test to verify that ethyne is unsaturated.** <u>**3×3**</u>

bubble gas into bromine or bromine water // into acidified potassium permanganate …3
orange / yellow / red / brown // purple …3
decolourises / to colourless …3

**(*g*) Give a major use for ethyne gas.** <u>**3**</u>

(in oxyacetylene) cutting metals or welding …3

**Ethyne can be converted into other useful organic compounds including X, Y and Z as shown in Figure 15.**

**(*g*) Name the compounds X, Y and Z.** <u>**9**</u>

X: ethene …3
Y: ethanal …3
Z: benzene …3

**Name the reaction type when ethyne is converted to compound X.** <u>**3**</u>

addition /hydrogenation …3

**Question 12**

**Answer any three parts.** **3×22**

**Question 12 (*a*)**

**Name the scientist pictured in Figure 16 who first applied quantum theory to the energy of electrons in atoms.** **2**

(Niels) Bohr …2

**Define**

**(i) an atomic energy level** **2×2**

definite or fixed or specific energy …2

of an electron in an atom …2

[atom omitted (–1)]

**(ii) an atomic orbital** **2×4**

region in space (in an atom) / region around nucleus (of an atom) …4

where there is a high probability of finding an electron …4

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

$1s^2 2s^2 2p^6$ …3

$3s^2$ ….3

**State how many orbitals are occupied by electrons in a magnesium atom in its ground state.** **2**

six …2

**Question 12 (*b*)**

**Figure 17 shows an apparatus used in the electrolysis of acidified water using inert electrodes.**

**Which electrode, A or B, is the cathode?** **2**

B …2

**What gas is collected above the cathode?** **2**

hydrogen …2

[accept oxygen if A given in previous answer]

**Write a balanced equation for the cathode reaction.** **2×3**

$2H_2O + 2e^- \rightarrow 2OH^- + H_2$

correct reactants and products …3

balanced …3

[allow $2H^+ + 2e^- \rightarrow H_2$ ….3]

[accept $H_2O \rightarrow \frac{1}{2} O_2 + 2H^+ + 2e^-$ / $2OH^- \rightarrow \frac{1}{2} O_2 + H_2O + 2e^-$ if oxygen accepted in previous answer]

**A current of 0.60 A was passed through the acidified water for 8 minutes.**

**What volume of gas, measured at STP, was produced at the cathode?** **6×2**

$t = 8 \times 60 = 480$ (s) …2

$Q = It$ …2

$Q = 0.6 \times 8 \times 60 = 288$ C …2

$288 \div 96485 = 0.003$ (moles electrons) …2

0.0015 moles hydrogen gas …2

$0.0015 \times 22\,400 = 33.6\ cm^3 = 0.0336$ L …2

**Question 12 (*c*)**

**The following balanced equation shows the reaction between a sodium hydroxide solution and aluminium metal.**

$$\mathbf{2Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2}$$

**When 10.8 g of aluminium is added to excess dilute sodium hydroxide solution, calculate**

**(i) the number of moles of water that react**

**(ii) the mass of sodium aluminate ($NaAlO_2$) produced**

**(iii) the number of hydrogen molecules formed** **6×3**

($A_r$) = 27 / 26.98

$\frac{10.8}{27} = 0.4$ (moles Al) / $\frac{10.8}{26.98} = 0.4$ (moles of Al) …3

0.4 moles water …3

0.4 moles sodium aluminate produced

($M_r$) = 82/ 81.97 …3

0.4 × 82 = 32.8 g / 0.4 × 81.97 = 32.788 (g) …3

0.6 (moles hydrogen gas produced) …3

$0.6 \times 6 \times 10^{23} = 3.6 \times 10^{23}$ (molecules hydrogen gas produced) …3

**Suggest a reason why sodium hydroxide solution should not be stored in aluminium containers.** **4**

NaOH reacts with aluminium / to avoid explosion / to avoid leak / to avoid reaction / to avoid pressure build-up …4

[safety...2]

**Question 12 (*d*)**

**State *Hess's law.*** <u>**2×2**</u>

heat change for a reaction …2

independent of path taken / depends only on initial and final states …2

**Consider the following reactions:**

$$\mathbf{C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} \qquad \Delta H = -393.5\ kJ\ mol^{-1}}$$
$$\mathbf{C_{(s)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow CO_{(g)} \qquad \Delta H = -110.5\ kJ\ mol^{-1}}$$
$$\mathbf{\tfrac{1}{2}N_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow NO_{(g)} \qquad \Delta H = 91.3\ kJ\ mol^{-1}}$$

**Use Hess's law and the heats of formation above to calculate the heat of reaction for the following conversion that occurs in the catalytic converter in a car exhaust system.**

$$\mathbf{2NO_{(g)} + 2CO_{(g)} \rightarrow 2CO_{2\,(g)} + N_{2\,(g)}}$$ <u>**4×4**</u>

$$2NO_{(g)} \rightarrow N_{2\,(g)} + O_{2\,(g)} \qquad \Delta H = -182.6\ \text{kJ mol}^{-1}$$ …4

$$2CO_{(g)} \rightarrow 2C_{(s)} + O_{2\,(g)} \qquad \Delta H = 221.0\ \text{kJ mol}^{-1}$$ …4

$$2C_{(s)} + 2O_{2\,(g)} \rightarrow 2CO_{2\,(g)} \qquad \Delta H = -787.0\ \text{kJ mol}^{-1}$$ …4

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$$2NO_{(g)} + 2CO_{(g)} \rightarrow 2CO_{2\,(g)} + N_{2\,(g)} \qquad \Delta H = -748.6\ \text{kJ mol}^{-1}$$ …4

**Explain why the product gases of this reaction are environmentally less harmful than the reactant gases.** <u>**2**</u>

NO acidic / NO toxic / $N_2$ inert /product gases already part of atmosphere /
CO toxic / $CO_2$ less toxic/ $CO_2$ can be used /removed from the air in photosynthesis …2

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