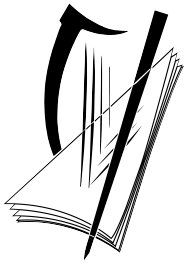


Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2018

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.

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

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

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

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

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

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

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

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

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

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

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

Coimisiún na Scrúduithe Stáit

400@10%

Marcanna Breise as ucht freagairt trí Ghaeilge

Léiríonn an tábla thíos an méid marcanna breise ba chóir a bhronnadh ar iarrthóirí a ghnóthaíonn níos mó ná 75% d'iomlán na marcanna.

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

Tábla 400 @ 10%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 400 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 300 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais
301 - 303	29
304 - 306	28
307 - 310	27
311 - 313	26
314 - 316	25
317 - 320	24
321 - 323	23
324 - 326	22
327 - 330	21
331 - 333	20
334 - 336	19
337 - 340	18
341 - 343	17
344 - 346	16
347 - 350	15

Bunmharc	Marc Bónais
351 - 353	14
354 - 356	13
357 - 360	12
361 - 363	11
364 - 366	10
367 - 370	9
371 - 373	8
374 - 376	7
377 - 380	6
381 - 383	5
384 - 386	4
387 - 390	3
391 - 393	2
394 - 396	1
397 - 400	0

Question 1
Any eleven parts **11×6**

(*a*) State Newton's law of universal gravitation. **2×3**
force between (any) two (point) masses is proportional to the product of their masses ….3
and inversely proportional to the square of the distance between them or their centres …3

or

$F = \frac{GMm}{d^2}$ / $F \propto \frac{GMm}{d^2}$ / $F = \frac{GM_1M_2}{r^2}$ …6
['sum' instead of 'product' …(−3)][square of distance omitted …(−3)]

(*b*) Distinguish between mass and weight. **6, 2×3**
weight is mass × acceleration due to gravity / $W = mg$ …6

or

mass: body's ability to resist acceleration or motion / measure of a body's inertia /
(a measure of the) quantity of matter in a body / (a measure of) strength of a body's mutual gravitational attraction to other bodies …3
weight: force with which earth attracts a body …3

[Accept 'mass is a scalar; weight is a vector' …6]

(*c*) Figure 1 is a velocity time graph for an object.
(*i*) What is its acceleration between B and C?
(*ii*) What is the distance travelled between C and D? **4, 2**
(*i*) ($v = u + at$ / $8 = 0 + 2a \Rightarrow$) $8 \div 2 = 4$ (m s^{-2})

(*ii*) ($s = vt \Rightarrow$) $8 \times 4 = 32$ (m) / ($s = ut + \frac{1}{2}at^2$ / $s = 8 \times 4 + \frac{1}{2}[0 \times (4)^2] \Rightarrow$) $8 \times 4 = 32$ (m)
first correct…4, second correct…2

(*d*) Define the unit of work, i.e. the joule. **2×3**
force of one newton or 1 N causes …3
movement through one metre (in direction of force) / point of application of force to move 1 m …3
[Allow …3 for definition of work as 'force × displacement' or 'force × distance in direction of force'.]

(*e*) The energy of a photon in a beam of *x*-rays is 1.5 ×10^{-15} J.
Calculate the frequency of the associated *x*-rays. **2×3**
$E = hf$ / $1.5 \times 10^{-15} = 6.626 \times 10^{-34} \times f$ ...3
(f =) 2.26×10^{18} (Hz) …3

(*f*) Arrange the following forms of electromagnetic radiation in order of *increasing* wavelength. **6**
radio waves infrared radiation gamma rays blue light
gamma, blue, infrared, radio …6
[Allow ...3 for reverse order or first and last correct.]

(*g*) State an energy conversion that takes place during the photoelectric effect. **2×3**
electromagnetic or light (energy) to / hf to …3
kinetic (energy) or $\frac{1}{2}mv^2$ / work function or hf_0 / heat / electrical (energy) …3
[reversed …3]
[Allow …3 for $hf = hf_0 + \frac{1}{2}mv^2$ without explanation.]

(*h*) State Boyle's law. **2×3**

volume of a fixed mass of gas at constant temperature / V at constant T //
pressure of a fixed mass of gas at constant temperature / p at constant T //
pV at constant T =//
p_1V_1 at constant T = // ...3
varies inversely with its pressure / $\propto 1/p$ //
varies inversely with volume / $\propto 1/V$ //
k / is constant //
p_2V_2 ...3
[omit 'fixed mass' (−1)]

(*i*) A constant volume gas thermometer, like that shown in Figure 2, is used as a standard thermometer. Why is a standard thermometer necessary? **6**

temperature varies with thermometric property chosen / thermometers using different thermometric properties disagree / to calibrate other thermometers …6

(*j*) According to kinetic theory, how is the behaviour of the molecules of a gas affected by
(*i*) an increase in the pressure of the gas,
(*ii*) a decrease in the temperature of the gas? **2×3**

(*i*) increase in frequency of collisions (between molecules and with container) /
greater forces involved in collisions (between molecules or with container) /
(average) kinetic energy (of particles or molecules) increased /
(particles or molecules) accelerate or move faster …3

(*ii*) kinetic energy (of particles or molecules) decreased /
(particles or molecules) decelerate or move slower /
(particles or molecules) collide less frequently (with one another or with container) /
smaller forces involved in collisions (between molecules or with container) …3

(*k*) Figure 3 shows a positively-charged, insulated, metal sphere A placed near an uncharged, insulated metal sphere B.
Draw a diagram to show how charge became distributed on B. **2×3**

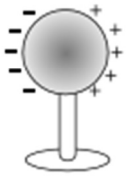


Figure 3

negative charge on left …3
positive charge on right …3

(*l*) Name a device based on the principle that a current carrying conductor in a magnetic field experiences a force. **6**

motor, meter, ammeter, voltmeter, multimeter, loudspeaker, etc …6

(*m*) What is the effect on the capacitance of a parallel-plate capacitor of increasing (*i*) the distance between the plates, (*ii*) the common area of the plates? **4, 2**

(i) (capacitance) reduced or smaller or decreased
(ii) (capacitance) increased or bigger

first correct…4, second correct…2

(*n*) What name is given to the following type of nuclear reaction?
$\mathbf{^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 3{}^{1}_{0}n}$ **+ energy** **3**

fission …3

Give an application for this type of reaction. **3**

energy source / nuclear reactor / weapons / nuclear or atomic bomb / etc …3

(*o*) What type of electromagnetic radiation can be emitted from a radioactive nucleus? **6**

gamma …6

Question 2

(*a*) (*i*) Define momentum. **6**

product of mass and velocity / *mv* / *m* × *v* / mass × velocity ...6

(*ii*) What is the S.I. unit of momentum? **3**

kilogram meter per second / kg m s^{-1} ...3

(*iii*) What quantity is proportional to the rate of change of momentum? **3**

force ...3

(*b*) When two moving objects have the same momentum,

(*i*) do they necessarily have the same speed **3**

no ...3

(*ii*) do their velocities necessarily have the same direction? **3**

yes ...3

Explain your answers. **2×3**

speed: they could have different masses (and different speeds) ...3

direction: velocity is the vector part of momentum / the direction of the velocity determines the direction of the momentum / velocity and momentum are vectors ...3

[Explain marks only available if correct response given to question(s).]

(*c*) State the *principle of conservation of momentum.* **2×4**

(in a system of colliding bodies) where no external force acts total momentum //

(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 $m_1u_1 + m_2u_2 =$ ...4

is constant //

is equal to total momentum after //

$m_1v_1 + m_2v_2$ or $(m_1 + m_2)v$ ...4

[where no external force acts omitted (–1)]

As part of an experiment to verify the principle of conservation of momentum, trolley A of mass 314 g was set in motion with constant velocity on a runway. It travelled 11.2 cm in 0.20 s. It collided with trolley B of mass 326 g that was initially at rest. Both trolleys then moved together with constant velocity and travelled 5.5 cm in 0.20 s.

State one precaution that should be taken to ensure that the trolleys run at constant velocity. **6**

eliminate friction / use a sloped track / lubricate the trolley wheels / sand the runway / polish the runway / remove dust / use an air track ...6

Calculate

(*i*) the initial velocity of A, **2**

11.2 cm in 0.2 s $\Rightarrow$ 11.2 × 5 = 56 cm s^{-1} = 0.56 m s^{-1} ...2

[no unit or incorrect unit (–1) but once only in (*i*) and (*ii*)]

(*ii*) the velocity of A and B combined after the collision, **2**

5.5 cm in 0.2 s $\Rightarrow$ 5.5 × 5 = 27.5 cm s^{-1} = 0.275 m s^{-1} ...2

[no unit or incorrect unit (–1) but once only in (*i*) and (*ii*)]

(*iii*) the total momentum before the collision, **3**

(0.314 × 0.56) = 0.17584 kg m s^{-1} / (314 × 0.56) = 175.84 g m s^{-1} / (314 × 56) = 17584 g cm s^{-1} ...3

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

(*iv*) the total momentum after the collision. **3**

(0.640 × 0.275) = 0.17600 kg m s^{-1} / (640 × 0.275) = 176.00 g m s^{-1} / (640 × 27.5) = 17600 g cm s^{-1} …3

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

[If no marks given for calculation (*i*), (*ii*), (*iii*) and (*iv*) allow …3 for $m_1u_1 + m_2u_2 = (m_1 + m_2)v$ given as part of attempt.]

Do these results verify the principle of conservation of momentum? **3, 6**
Justify your answer.

yes or results the same or results do not vary // no or results different …3

momentum before collision = momentum after / $m_1u_1 + m_2u_2 = (m_1 + m_2)v$
(within experimental error or correct to three significant figures) //
momentum before collision ≠ momentum after (here) …6

Juno, shown in Figure 4, is a space probe that was launched in August 2011 and approached the planet Jupiter in July 2016 at a velocity of 210,000 km per hour. Its total mass at that time was 2,825 kg. To reduce its speed in the same direction to 208,050 km per hour for successful entry into an orbit around Jupiter it burned some fuel and expelled 447 kg of hot combustion gases into space.
Calculate the velocity, in km per hour, with which the gases were expelled. **3×3**

$(m_1 + m_2)v = m_1v_1 + m_2v_2$ …3

(initial momentum Juno =) 2825 × 210000 / (initial momentum Juno =) 5.9325 × 10^8 /
(final momentum Juno =) 2378 × 208050 / (final momentum Juno =) 4.947429 × 10^8 /
(change in momentum Juno =) 9.85071 × 10^7 (= momentum gases expelled 447 × *v*) …3

($\Rightarrow$ *v* =) 2.20 × 10^5 km h^{-1} / 220373.8 km h^{-1} …3

[no unit or incorrect unit (–1)]

Question 3

(*a*) Figure 5 shows a ray of light from a ray box passing through a transparent, semi-circular plastic block and back into air at O.

(*i*) Name and state the law that describes the relationship between the angle X and the angle Y. **3×3**

Snell's law …3

sine of angle of incidence is proportional to // sin$i \propto$ // ratio of sine of angle of incidence and sine of angle of refraction // $\frac{\sin i}{\sin r}$ …3

the sine of the angle of refraction // sin*r* // is constant // = *n* or constant …3

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

(*ii*) Explain why the incident ray is *not* refracted at P. **3**

it coincides with a radius (of the semi-circular block) /
strikes parallel to the normal at point where it strikes (plastic-air boundary) /
strikes perpendicular to (tangent to) plastic-air boundary /
angle of incidence is zero …3

(*iii*) Calculate the refractive index of the plastic if X = 30° when Y = 48°. **4, 2**

$\frac{sini}{sinr}$ / $\frac{sin48}{\sin 30}$ / $\frac{0.7431}{0.5}$ // $\frac{sini}{sinr}$ / $\frac{sin30}{\sin 48}$ / $\frac{0.5}{0.7431}$ …4

(*n* =) 1.4862 – 1.5 // (1/*n* = 0.6728 $\Rightarrow$ *n* =) 1.4862 – 1.5 …2

(*iv*) Explain how this apparatus could be used to find the critical angle for this plastic. **2×3**

increase angle of incidence …3

until refracted ray exits block parallel to straight face / until Y = 90° …3

[Information available from clear, labelled diagrams; no labels (–1).]

(*v*) Calculate the critical angle for the plastic. **4, 2**

$n = \frac{1}{sinc}$ / 1.4862 = $\frac{1}{sinc}$ / $sinc = \frac{1}{n}$ / $sinc = \frac{1}{1.4862}$ / $sinc = 0.6728$ …4

$\sin^{-1}(0.6728) = 42.29°$ / $42.3°$ …2

(*vi*) What happens at O when the critical angle is exceeded? **6**

reflection (of all the light) / total internal reflection …6

[total internal refraction instead of total internal reflection …(–3)]

(*b*) Distinguish, in terms of light rays, between a real and a virtual image. **2×3**

real image formed by the (actual) intersection of light rays …3

virtual image formed by the apparent intersection of light rays / virtual image formed when light rays appear to meet …3

[real image formed on a screen, virtual image cannot be formed on a screen …3]

(*c*) An object was placed at the same fixed distance (*u*) from a number of different convex lenses of different focal lengths (*f*). The image distance (*v*) for each lens was found. Values for 1/*f* and 1/*v* are given in the table.

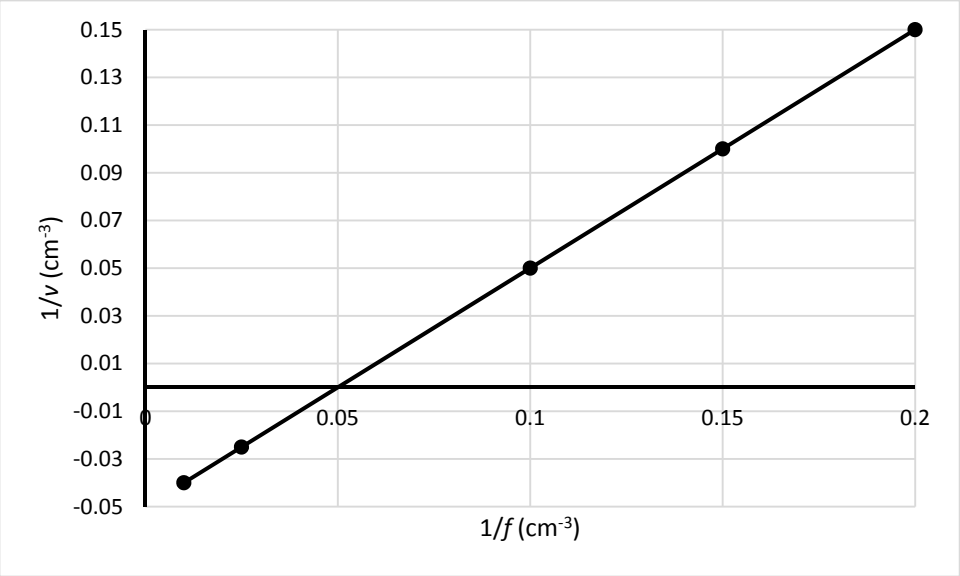
1/*f* (cm^{-1})	**0.20**	**0.15**	**0.10**	**0.025**	**0.010**
1/*v* (cm^{-1})	**0.15**	**0.10**	**0.05**	**–0.025**	**–0.040**

(*i*) What is the significance of the negative 1/*v* values? **3**

virtual images / images cannot be formed on a screen /
images formed by apparent intersection of light rays / object inside focus …3

(*ii*) Draw a graph of 1/*v* *versus* 1/*f* (*x*-axis). **4×3**

axes labelled 1/*v* *and* 1/*f* …3
axes drawn with appropriate scales …3
four points correctly plotted (only if scales appropriate) …3
straight line through these points ...3
[Allow axes reversed.]



(*iii*) Hence or otherwise find *u*. **6, 3**

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ / intercept on *x*-axis 1/*f* = 1/*u* / 0.05 = 1/*u* ...6
insert any values from table or graph into $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \Rightarrow$
(*u* =) 20 cm …3
[no unit or incorrect unit (–1)]

Question 4

(*a*) Define temperature. **2×3**

measure of // measure of (condition of a body that determines) …3
hotness / how hot or cold (an object is) //
whether heat flows in or out of it / how heat is transferred to (or from) it …3

(*b*) State Charles' law. **2×3**

the volume of a fixed mass of gas at constant pressure …3
is proportional to its temperature on the Kelvin or absolute scale / increases by 1/273 for every degree change in temperature …3
[fixed mass gas omitted (–1)][Kelvin omitted (–1)]

or

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ / $\frac{V}{T}$ is constant / $\frac{V}{T} = k$ / $V \propto T$ …6

(*c*) What is meant by the absolute scale of temperature? **6**

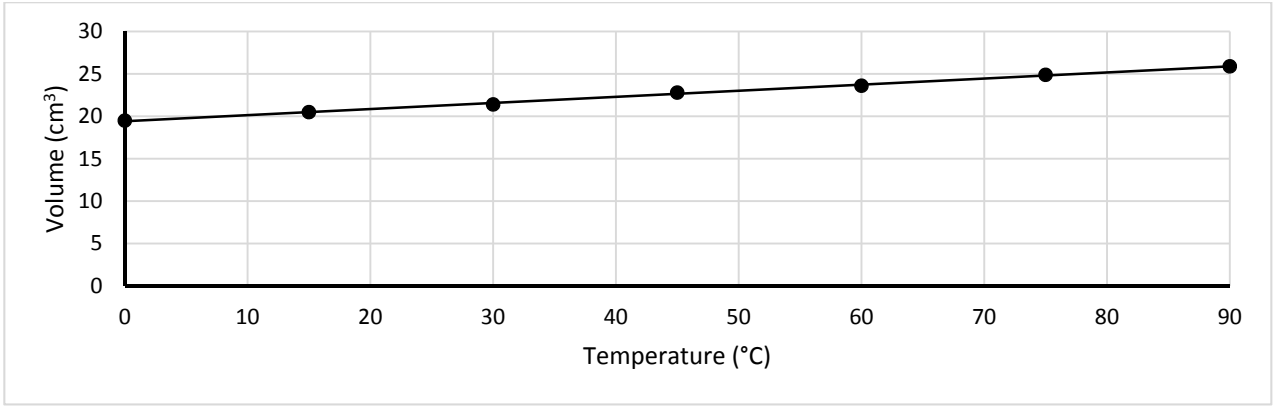
where the lower (reference or fixed) point is absolute zero or zero Kelvin or –273.15 °C /
where the upper (reference or fixed) point is triple point of water or 273.16 K or 0.01 °C /
temperature scale where zero corresponds to an ideal gas having zero volume /
scale based on volume proportional to temperature /
$\frac{T}{273.16} = \frac{V_T}{V_{tp}}$ / $\frac{T}{273.16} = \frac{P_T}{P_{tp}}$ …6
[Allow …6 for 'Kelvin scale' or 'ideal gas temperature scale'.]

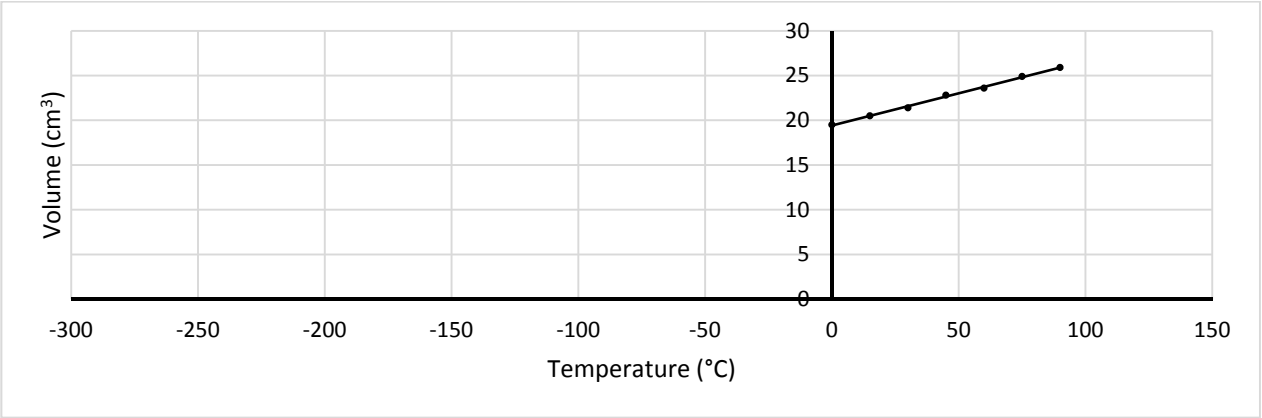
(*d*) A syringe containing a fixed mass of air was immersed in a number of water baths at different temperatures. The pressure was kept constant at 1.1 × 10^5 Pa. The data below were obtained for the volume of the air at each of these temperatures.

Volume (cm^3)	19.5	20.5	21.4	22.8	23.6	24.9	25.9
Temperature (°C)	0.0	15	30	45	60	75	90

(*i*) Plot a graph of volume (*y*-axis) versus temperature in °C. **4×3**

axes correctly labelled volume or cm^3 or *V* and temperature or °C …3
[Allow *T* to label temperature axis.]
axes drawn with appropriate scales …3
six points correctly plotted …3
straight line through these points …3



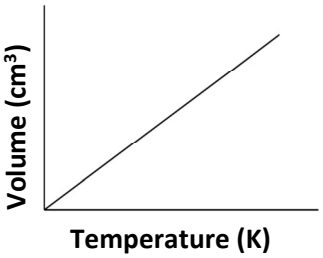


[–273.15 °C need not be shown and may be included in straight line if shown.][Allow axes reversed.]
[Where graph of volume versus temperature (K) is plotted, maximum mark …9]

(*ii*) Explain how your graph could be used to find the value for absolute zero on the Celsius scale. **6 or 2×3**

where extended (extrapolated) graph intercepts *x*-axis (temperature axis) …6
or
where –273.15 °C is shown: absolute zero can be read from graph where $V = 0$ cm^3 …6
or
where –273.15 °C is not shown: x value (temperature value) can be obtained from
equation of line or from $y = mx + c$ or from $y - y_1 = m(x - x_1)$ …3
where $y = 0$ …3

(*iii*) Sketch the graph you would expect to obtain if the volume of the air in the syringe is plotted versus *absolute* temperature. **2×3**



axes labelled volume and temperature …3
straight line graph (through origin or if extrapolated would clearly go through or near origin) …3

How would this graph verify Charles' law? **3**
straight line through origin (shows volume proportional to absolute temperature) /
straight line through origin (shows $\frac{V}{T}$ is constant) …3
[take through origin as given if not stated but drawn in diagram]

(*iv*) Give a reason why is it not possible to measure the actual volume of air in the syringe at absolute zero. **6**
air would be frozen or condensed / air would not be gaseous / absolute zero cannot be reached / absolute zero difficult to reach / absolute zero is a theoretical concept / air is not an ideal gas, etc …6

(*v*) Calculate the number of moles of oxygen gas in the syringe if the air contained 21% oxygen by volume. **2×3, 6, 3**
21% of a volume from table or graph …3
corresponding temperature + 273 ….3
$PV = nRT$ …6
$(1.1 \times 10^5 \times (4.095 \times 10^{-6}) = n \times 8.31 \times (273) \Rightarrow n =) 1.99 \times 10^{-4} / 2 \times 10^{-4}$ (moles) …3
[Volume not in m^3 or answer a multiple of correct number of moles …(−1)]

Question 5

(*a*) Define (*i*) electric current, **3**

flow of charge or electrons …3

(*ii*) the unit of current, i.e. the ampere. **3×3**

current flowing in two *long, thin* wires …3

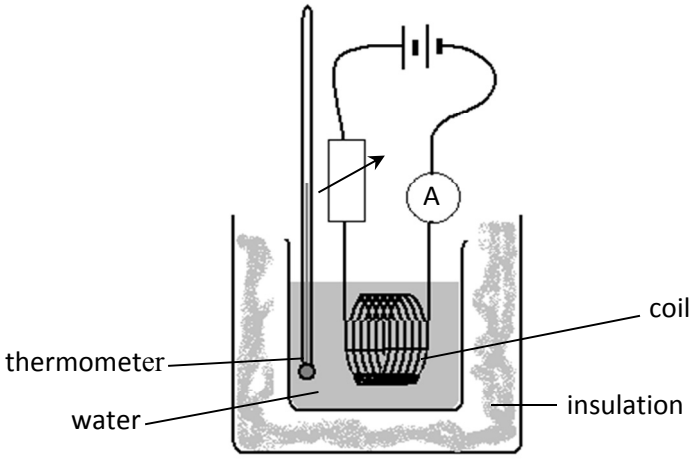
1 m apart *in a vacuum* …3

when force exerted by each on the other is 2×10^{-7} *N* m^{-1} ...3

[Deduct 1 mark for each phrase in italics omitted.]

(*b*) Heat is produced when electric current flows through a metallic conductor. The heat produced in a given time is proportional to the square of the current flowing when the resistance of the conductor is kept constant.

Using a labelled diagram of the apparatus, describe an experiment to verify this relationship. **6×3**



battery, ammeter, coil /

insulated container or lid on container /

(known) mass of water in container (of known mass) /

thermometer in water /

mention or sketch of timer /

use of variable resistor to keep current constant

[no labels …(−1); take A for ammeter as a label]

any three …3×3

vary current flowing

use same mass water for every new current

measure temperature rise

temperature rise proportional to heat produced

straight line through origin for graph of temperature versus I^2

any three …3×3

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

production or induction of an emf or current …3

when there is relative motion between a conductor and a magnetic field /

when there is a changing magnetic field or flux around the conductor …3

(*d*) Transformers are used in the supply of electricity from a generating station to your home. Explain how a transformer like that shown in Figure 6 works. **3×3**

a.c. supply or input current or input voltage or a.c. in primary …3

electromagnetic induction occurs / changing magnetic field through input coil or output coil …3

generates output voltage or output emf or emf in secondary …3

(*i*) State two ways of reducing energy losses in a transformer. **2×3**

laminate the core / soft iron core / wind coils tightly / use low resistance material for wire in coils / use thicker wire in coils / cool the transformer / shape or design of core to avoid flux leakage / etc

any two…2×3

(*ii*) What is the ratio of turns in the primary coil compared with the secondary coil if the input voltage is 3,450 V and the output voltage is 230 V? **6**

$\frac{3450}{230} = \frac{N_p}{N_s}$ …3

$\Rightarrow$ 15 : 1 / $\frac{15}{1}$ …3

[1:15 allow …3]

(*e*) Explain, in terms of heat produced in the cables, why electricity is transmitted at high voltage from a power station to a transformer near your home. **6, 3**

the bigger the current the more heat produced or lost or wasted in the cables

according to RI^2 low current keeps energy loss due resistance in cables low /

(according to $P = VI$) low current requires high voltage (to deliver same power)

first correct ….6, second correct …3

Question 6
Answer any two parts

Question 6 (*a*)
State the principle of conservation of energy. **6**
total energy in a system is unchanging / energy cannot be created or destroyed …6
[Allow $\Delta E_p + \Delta E_k = 0$ …3 or $\Delta E_p + \Delta E_k = 0$ under conservative mechanical forces …6]

In a curling match a competitor released a stone of mass 18.0 kg, like that shown in Figure 7, with kinetic energy of 20.25 J and it travelled 12.5 m across ice in a straight line before coming to rest. Calculate

(*i*) the initial velocity of the stone, **3×3**
(E=) ½ mv^2 …3
$20.25 = ½ \times 18 \times v^2$ …3
($\Rightarrow v = \sqrt{\frac{20.25 \times 2}{18}}$ =) 1.5 m s^{-1} …3
[no unit or incorrect unit …(−1)]

(*ii*) the deceleration of the stone, **2×3**
$v^2 = u^2 + 2as$ / $0^2 = 1.5^2 + 2 \times a \times 12.5$ / $-2.25 = 25 \times a$ …3
(a = −) 0.09 m s^{-2} ...3
[no unit or incorrect unit …(−1)][either positive or negative answer acceptable]

(*iii*) the force that brought the stone to rest, **3**
($F = ma \Rightarrow F = 18 \times -0.09$ =) −1.62 N (newtons) …3
[no unit or incorrect unit …(−1)] [either positive or negative answer acceptable]

(*iv*) the time taken for the stone to come to rest. **2, 1**
$v = u + at$ / $0 = 1.5 - 0.09 \times t$ …2
($\Rightarrow t$ =) 16 2/3 / 16.7 s …1
[no unit or incorrect unit …(−1)][negative answer …(−1)]

Name the horizontal force that brought the stone to rest. **3**
friction / resistance ….3

What happened to the 20.25 J of kinetic energy? **3**
converted into heat or sound or vibration or other forms of energy / absorbed by the ice ….3

Question 6 (*b*)

Three identical 4 Ω bulbs A, B and C are connected to a 12 V power supply as shown in the circuit in Figure 8.

Calculate

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

parallel: $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} / \frac{1}{R} = \frac{1}{4} + \frac{1}{4}$ …3

$\Rightarrow R = 2$ (Ω) …3

series: 2 + 4 = 6 Ω …3

(*ii*) the current flowing through A, **2×3**

$V = IR / I = \frac{V}{R}$ …3

($I = \frac{12}{6}$ =) 2 A …3

[no unit or incorrect unit …(−1)]

(*iii*) the potential difference across A, **2×3**

$V = IR$ …3

(V =) 2 × 4 = 8 V …3

[no unit or incorrect unit …(−1)]

(*iv*) the current flowing through B. **3**

12 – 8 = 4 V $\Rightarrow$

($I = \frac{4}{4}$ =) 1 A …3

[no unit or incorrect unit …(−1) but once only in (*ii*) and (*iv*)]

If switch S is opened, how is the brightness of A affected? **6**

dimmer / not as bright …6

Explain your answer. **3**

new resistance is 8 Ω or bigger than before /

current in circuit now 1.5 A or smaller than before …3

Question 6 (*c*)

Both <u>diffraction</u> and <u>interference</u> occur when a narrow beam of <u>monochromatic light</u> passes through a pair of narrow slits forming a pattern of bright and dark images on a screen.

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 …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

How does the formation of these images contribute to our understanding of the nature of light? **<u>6</u>**

light has a wave nature / light is not composed of particles / wavelength of light can be measured …6

Calculate the wavelength of the light used if the separation between the centres of the slits was 0.4 mm, the screen was placed 2.3 m from the slits and the distance from the central bright image to the 9th bright image was 3.5 cm. **<u>6, 3×2 or 6, 4, 2</u>**

$n\lambda = d\sin\theta$ …6

$\tan\theta = \frac{3.5 \times 10^{-2}}{2.3} = 1.52 \times 10^{-2}$ …2

$\sin\theta \approx \tan\theta = 0.01522$ / $\tan^{-1}0.01522 = 0.8718° \Rightarrow \sin\theta = 0.01522$ …2

$9\lambda = 4 \times 10^{-4} \times 0.01522 \Rightarrow$

$\lambda = 6.76 \times 10^{-7}$ m or 676 nm …2

[no unit or incorrect unit …(−1)][treat incorrect multiple of correct answer as incorrect unit or no unit]

or

$n\lambda = \frac{dx}{D}$ …6

$9\lambda = \frac{4\times10^{-4}\times 3.5 \times 10^{-2}}{2.3}$ …4

$\lambda = 6.76 \times 10^{-7}$ m or 676 nm …2

[no unit or incorrect unit …(−1)][treat incorrect multiple of correct answer as incorrect unit or no unit]

Question 6 (*d*)
What changes take place in the structure of the nucleus when
(*i*) alpha decay occurs, **6 or 2×3**
helium nucleus emitted or lost / two protons and two neutrons emitted or lost / $^{4}_{2}\mathrm{He}$ emitted or lost …6

or

two protons lost / atomic number decreased by 2 …3
two neutrons lost / mass number decreased by 4 …3

(*ii*) beta decay, occurs? **6**
a neutron changes into a proton / $^{1}_{0}n \rightarrow {}^{1}_{1}p$ / number neutrons decreases by one /
electron (e^{-}) is emitted / proton (atomic) number increases by one …6
['Beta-particle emitted' is not acceptable.]
[Accept for (6) 'mass is unchanged but atomic number increases by one'.]
[Accept for (6) 'a positron is emitted when a proton changes into neutron'.]

Compare the ionising abilities of alpha and beta particles.
Account for the difference in their ionising abilities. **6, 3**

alpha more ionising / beta less ionising

alpha has greater mass or heavier or larger / beta has smaller mass or lighter or smaller /
alpha has bigger charge / beta has smaller charge
first correct …6, second correct …3

Gold–198 is a beta particle emitter. It can be used by environmental scientists to trace the movement of sand in cases of coastal erosion. The graph in Figure 9 shows how the activity of a sample of Au–198 changes with time.
Write a nuclear equation to represent the beta-decay of Au–198. **6**
$^{198}_{79}\mathrm{Au} \rightarrow {}^{198}_{80}\mathrm{Hg} + {}^{0}_{-1}e$ / $^{198}_{79}\mathrm{Au} \rightarrow {}^{198}_{80}\mathrm{Hg} + {}^{0}_{-1}\beta$ / $^{198}_{79}\mathrm{Au} \rightarrow {}^{198}_{80}\mathrm{Hg} + \beta$ / $^{198}_{79}\mathrm{Au} \rightarrow {}^{198}_{80}\mathrm{Hg} + e^{-}$
…6

[one product correct …3]

Use Figure 9 to find the half-life of Au–198. **6**
2.7 to 2.8 (days) …6
[Allow …3 for 2.35 to 2.4 (days).]

Question 7
Any eleven parts **11×6**

(*a*) How many (*I*) electrons, (*ii*) neutrons, has the aluminium ion, $^{27}_{13}Al^{3+}$? **4, 2**
electrons: 10
neutrons: 14
first correct…4, second correct…2

(*b*) Define relative atomic mass. **2×3**
average mass of an atom of an element / mass of an atom taking isotope abundances into account …3
compared to (1/12th) carbon-12 …3
['average' or 'isotope abundances omitted' (–1)]

(*c*) Figure 10 shows buckminsterfullerene (C_{60}) an allotrope of carbon.
What are allotropes? **3**
different physical forms of the same element …3

Name an allotrope of carbon that can conduct electricity. **3**
graphite / graphene …3

(*d*) Write the chemical formula for zinc chloride. **2×3**
correct elemental symbols for zinc and chlorine …3
$ZnCl_2$ / Cl_2Zn …3

(*e*) 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)]['measure' omitted (–1)]

(*f*) Hydrides are binary compounds of hydrogen. Explain the underlined term. **3**
made up of two elements …3

Classify the hydride H_2S as ionic or covalent. **3**
covalent …3

(*g*) Na_2PO_xF, an additive in the toothpaste in Figure 11, contains 33⅓%, by mass, of oxygen.
What is the value of *x* in the formula? **2×3**
(O = 16, F = 19, Na = 23, P = 31)
(M_r =) 96 + 16x …3
($\frac{16x}{96+16x} = \frac{1}{3} / \frac{16x}{96+16x} = \frac{33}{100} \Rightarrow$) $x = 3$ …3

(*h*) Under what circumstances does sodium chloride conduct electricity? **6**
molten / dissolved in water / in solution ...6

(*i*) Classify sulfur dioxide as an amphoteric, an acidic, a basic or a neutral oxide. **3**
acidic …3

What environmental problem is caused by the presence of SO_2 in the atmosphere? **3**
acid rain / damage to trees or forests / damage to buildings or metals / causes asthma or breathing difficulties / etc …3

(*j*) Flask A contains helium gas and an identical flask B contains argon gas at the same temperature and pressure. Which flask, A or B or neither, contains

(*i*) the greater mass of gas, **3**

B /argon ...3

(*ii*) the greater number of atoms?

neither **3**

(*k*) Balance the equation: $Ga_2O_3 + HCl \rightarrow GaCl_3 + H_2O$ **6**

$Ga_2O_3 + 6HCl \rightarrow 2GaCl_3 + 3H_2O$ ...6

[Allow 3 for gallium balanced.]

(*l*) The heat of solution (ΔH) of sodium nitrate ($NaNO_3$) is 20.5 kJ mol^{-1}.
How much heat is absorbed when 17 g of sodium nitrate dissolves in water?
Does the temperature of the solution increase or decrease as the crystals dissolve?
(Take the M_r of $NaNO_3$ as 85.) **4, 2**

$\frac{17}{85} \times 20.5 = 4.1$(kJ) ...4

decrease ...2

(*m*) Identify the reagent required and the necessary condition for the following conversion of CH_4 to CH_3Cl. **2×3**

chlorine / Cl_2 ...3

ultraviolet (light) / uv (light) / sunshine ...3

(*n*) Copy Figure 12 of the structure of alanine, an amino acid used by living organisms to synthesise protein.

(*i*) Circle the methyl group in your structure. **3**

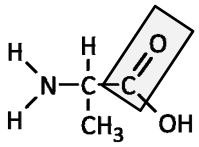


Figure 12

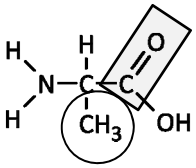


Figure 12 completed

...3

(*ii*) What is the group inside the box called? **3**

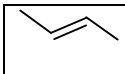
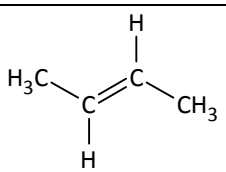
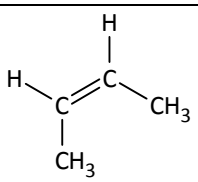
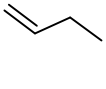
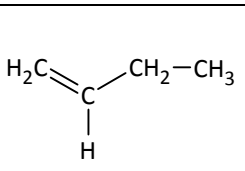
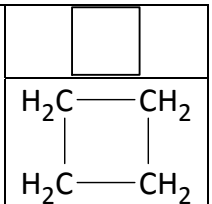
carbonyl ...3

(*o*) Draw the structure and name a compound that has the molecular formula C_4H_8. **2×3**

structure ...3

corresponding name ...3

[*Position* of double bond in butene omitted from name or incorrect (–1)]

  $CH_3CH{=}CHC_3$			 $CH_2{=}CHCH_2CH_3$		
2-butene or but-2-ene			1-butene or but-1-ene		cyclobutane

Question 8

Figure 13 represents the first six main energy levels of an atom as proposed by Neils Bohr about 1913. Sublevels and orbitals were introduced later to account for certain experimental observations.

(*a*) (*i*) What is the maximum number of electrons that can be accommodated in the *n* = 2 level? 3

8 …3

(*ii*) How many sublevels are associated with the *n* = 2 energy level? 3

2 …3

(*iii*) What is an atomic orbital? 2×4

region in space or volume (around the nucleus of an atom) …4

where the probability of finding an electron is high …4

['area' instead of 'region' or 'volume' (–1)]

(*iv*) How many orbitals are associated with the *n* = 2 energy level? 1

4 …1

(*b*) Copy the diagram and use it to help you account for the visible lines in the hydrogen emission spectrum. 3×3

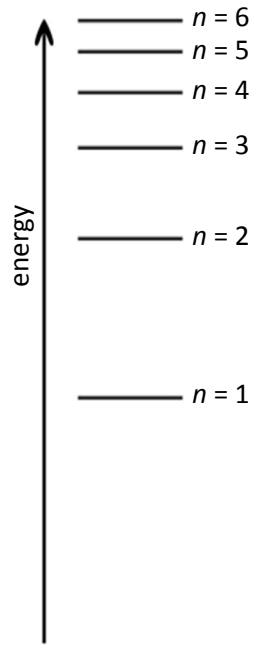


Figure 13

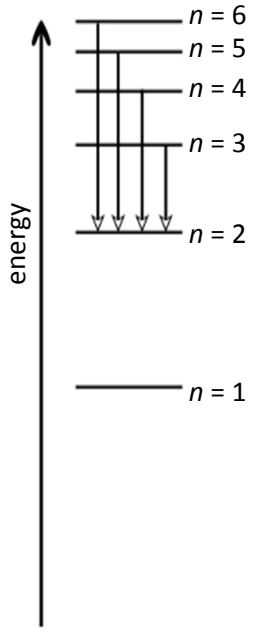


Figure 13 completed

electron (originally) in ground state or *n* = 1 /

*moves to higher levels or excited states or *n* ≥ 2 when given energy or heated either one …3

excited state or higher energy levels are temporary or unstable /

*electron falls back to *n*= 2 energy levels /

*arrows from higher levels to *n*= 2 any one …3

emitting light or electromagnetic radiation /

$E_2 - E_1 = hf$ either one …3

[Points with * may be obtained from diagram.][No use of diagram max …6]

(*c*) Flame tests provide evidence for energy levels in atoms.

(*i*) Describe how to carry out a flame test on an unknown salt. **3×3**

Method 1	Method 2	Method 3	
clean a platinum or nichrome wire* or rod or probe in concentrated hydrochloric acid or HCl	soak wood or splint, or stick overnight in water / use damp or wet wood or splint or stick	prepare a solution of the salt in water and ethanol or propanol or alcohol	…3
dip rod in salt and hold salt in or over hot or blue part of flame or Bunsen	dip splint or stick in salt and hold salt in or over hot or blue part of flame or Bunsen	spray solution onto or into hot or blue part of flame or Bunsen	…3
observe colour of flame	observe colour of flame	observe colour of flame	…3

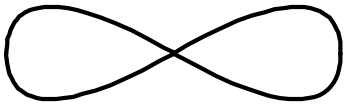
*[Allow 'inoculating loop', or 'spatula' for 'platinum wire'.]
[Clear labelled diagram for some or all points acceptable.]

(*ii*) What metallic element when present in a salt produces a lilac flame? **3**
potassium or K …3

(*d*) One of the electrons in an atom is described by the set of quantum numbers {3, 1, –1, –½}.

(*i*) What main energy level is occupied by this electron? **3**
third or (*n* =) 3 …3

(*ii*) Draw the shape of the orbital occupied by this electron. **6**



…6

[Allow a set of dumbells.]
[Allow …3 for circle or sphere.]

(*e*) Figure 14 shows the successive ionisation energies for all the electrons of element X.

(*i*) Define *first ionisation energy*. **6×1**
minimum /
energy (required) /
to remove completely /
the most loosely bound or outermost electron /
from a neutral /
gaseous atom /
in its ground state /
measured in kJ per mole

any six …6×1

(*ii*) Identify element X and write its *s*, *p* electron configuration. **3, 6, 3**
aluminium or Al …3
$1s^2\ 2s^2\ 2p^6$ ...6
$3s^2\ 3p^1$ / $3s^2\ 3p_x^1$ ...3

(*iii*) Why is there a sharp increase from the 11th to the 12th ionisation energy? **3**
(twelfth electron) taken from new or first (main) energy level or shell or from *n* = 1 /
(twelfth electron) taken from close to nucleus /
(twelfth electron) taken from stable shell / (twelfth electron) taken from a full or inner shell …3

Question 9

Limewater is a <u>saturated solution</u> of calcium hydroxide ($Ca(OH)_2$) in water. The concentration of a freshly prepared, filtered limewater solution was found by titration with a <u>standard solution</u> of hydrochloric acid. A 0.045 M solution of hydrochloric acid was titrated against three 20.0 cm^3 portions of the limewater using methyl orange indicator.

The balanced equation for the reaction is:

$$Ca(OH)_2 + 2HCl \quad CaCl_2 + 2H_2O$$

(*a*) Explain the underlined terms. **<u>9, 3</u>**

saturated solution: (solution with) maximum quantity or mass or amount of solute or solid or $Ca(OH)_2$ dissolved (at that temperature)

standard solution: (solution of exactly) known concentration

first correct ….9, second correct…3

(*b*) Give a common use for limewater in the laboratory. **<u>6</u>**

to detect presence of carbon dioxide or CO_2 (gas) …6

Why is it necessary to keep a limewater solution stoppered whenever possible? **<u>3</u>**

to prevent it absorbing carbon dioxide or CO_2 (gas) / to prevent it reacting with air / not stable in air / to prevent it changing concentration …3

(*c*) The piece of apparatus X in Figure 15 was used to add the HCl solution to the limewater in a titration flask. X was filled to the zero mark before commencing each titration.

(*i*) Name X. **<u>6</u>**

burette ...6

(*ii*) Describe how X was rinsed before use. **<u>2×4</u>**

rinse with deionised or distilled water …4

rinse with hydrochloric acid or HCl / rinse with solution it is to deliver or hold …4

(*iii*) Use the end point readings A, B and C, shown in Figure 15, for the three titrations to determine the correct average volume of HCl needed to neutralise 20.0 cm^3 of the limewater. **<u>2×1</u>**

reading burette correctly: (18.9) 18.3 and 18.4 …1

averaging two burette readings: (18.3 + 18.4) ÷ 2 = 18.35 (cm^3) …1

[misreading burette readings and then averaging two …1]

(*iv*) How could the presence of an air bubble in the nozzle of X have affected the result obtained in a titration reading? **<u>2</u>**

reading (could be) too big / reading (could be) inaccurate …2

(*d*) State the colour change observed at the end point in the conical flask. **<u>2×3</u>**

yellow or orange ...3

orange or pink ...3

[allow 3 if colours are reversed]

(*e*) Calculate the concentration of the limewater in

(*i*) moles per litre, **2×3**

$\frac{V_1 \times M_1}{n_1} = \frac{V_2 \times M_2}{n_2} / \frac{18.35 \times 0.045}{2} = \frac{20 \times M_2}{1} /$

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

(M_1) = 0.021 (M) [0.0206 – 0.021 M] ...3

or

moles of HCl used in 18.35 cm^3 = $\frac{18.35 \times 0.045}{1000}$ =

0.00082575 ...3

0.00087075 ÷ 2 = 0.000412875 moles of limewater $\Rightarrow \frac{0.000412875 \times 1000}{20}$ =

0.021 (moles /L) [0.0206 – 0.021 M] …3

(*ii*) grams per litre. **2×3**

(M_r of $Ca(OH)_2$ =) 74 ...3

0.021 × 74 = 1.554 (g /L) [1.48 – 1.56 g / L] ...3

(*f*) Define pH. **3**

pH = – log[H^+] ...3

[pH is a measure of the H^+ ion concentration (–1)]

Calculate the pH of the limewater solution. **3×2**

pOH = (–$\log_{10}$[OH^-]) = –$\log_{10}$(0.042) = 1.38 or 1.4 ...3

pH = 14 – pOH = 12.6(2) …3

Question 10

Six metals are listed below in order of their *decreasing* ease of oxidation.

magnesium aluminium zinc iron copper platinum

(*a*) Define in terms of electron transfer, **6, 3**

(*i*) oxidation,

(oxidation is the) loss of electrons

(*ii*) oxidising reagent.

substance that gains electrons / substance that causes loss of electrons in another substance

first correct …6, second correct …3

(*b*) From the list above, select **6, 2, 1**

(*i*) the strongest reducing agent,

magnesium

(*ii*) the metal whose ions are the most difficult to reduce

magnesium

(*iii*) the metal that reacts most vigorously with steam.

magnesium

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

(*c*) What reaction, if any, would you expect to occur if a wire made of iron was placed **2×3**

(*i*) in a copper(II) sulfate solution,

iron or wire reacts with copper ions / blue colour of copper sulfate fades or disappears /

$Fe + CuSO_4 \rightarrow$ …3

to give copper metal / to give iron sulfate solution / $\rightarrow FeSO_4 + Cu$ …3

(*ii*) in a zinc sulfate solution? **3**

no reaction …3

(*d*) An aluminium object resists corrosion by means of a layer of metal oxide that forms on its surface. Why can an iron object not resist corrosion in the same way? **2×3**

rust falls off / iron oxide layer permeable …3

exposing metal to new corrosion or to water and air …3

(*e*) Figure 16 shows water, acidified by the addition of a few drops of concentrated sulfuric acid, undergoing electrolysis using platinum electrodes. Oxygen gas was liberated at one of the electrodes according to the following equation.

$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$

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

using electricity to bring about a chemical reaction / using electricity to split water into its elements …6

(*ii*) Write a balanced equation for the reaction that occurs at the other electrode. **2×3**

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ / Allow $2H^+ + 2e^- \rightarrow H_2$

formulae correct….3

balancing correct…3

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

positive / left hand electrode / anode / A …3

Justify your answer. **3**

left or A is the positive electrode or left or A is the anode / loss of electrons at positive or left electrode or anode or at A / water loses electrons at anode or at A …3

[Justify marks only available if correct electrode identified for oxidation.]

(*iv*) How many moles of electrons are required to liberate one mole of O_2 in the reaction above? **1**

4 …1

(*v*) What charge, in coulombs, liberates 0.0056 moles of O_2? **2×3**

4 × 0.0056 = 0.0224 (moles electrons) …3

0.0224 × 96485.3383 = 2161.27 – 2161.6 (C) …3

[Accept 96,500 for Faraday's constant.]

(*vi*) Calculate the current used if the 0.0056 moles of O_2 was liberated in 30 minutes. **4, 2×2**

$Q = It$ …4

$t = 30 \times 60 = 1800$ (s) / $2161.27 = I \times (30 \times 60)$ / $I = \frac{2161.27}{30 \times 60}$ …2

(I =) 1.2 (A) …2

(72 (A) worth …6]

Question 11
Study the reaction scheme in Figure 17 and answer the questions that follow.

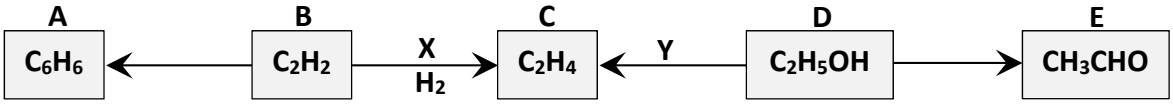


Figure 17

(*a*) (*i*) What is a functional group? **2×3**
an atom or a group of atoms or a type of bond that …3
gives an (organic) compound characteristic chemical properties …3

(*ii*) What is a homologous series? **3**
series of compounds with the same functional group /
series of compounds with the same general formula /
series of compounds with same chemical properties /
series of compounds with gradation in physical properties /
series of compounds with similar method of formation any one …3

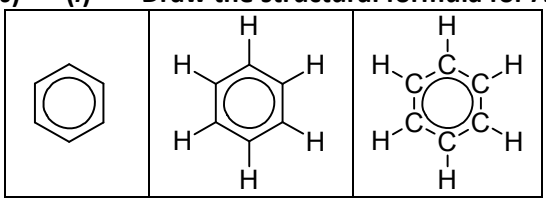
(*b*) Name
(*i*) compounds A, B, C, D and E, **5×3**
(A =) benzene …3
(B =) ethyne …3
(C =) ethene …3
(D =) ethanol …3
(E =) ethanal …3

(*ii*) catalysts X and Y, **2×3**
(X =) nickel, platinum, copper …3
(Y =) aluminium oxide or alumina / (concentrated) sulfuric acid …3
[Accept elemental symbols and Al_2O_3 and H_2SO_4.]

(*iii*) the homologous series to which E belongs, **3**
aldehyde(s) …3

(*iv*) the type of reaction involved in the conversion of D to E. **3**
oxidation / dehydrogenation …3

(*c*) (*i*) Draw the structural formula for A. **6**



any one…6

[accept structure with localised double bonds …3]

(*ii*) Describe the bonding in A. **2×3**
covalent /
aromatic /
single bond between each carbon and a hydrogen atom /
alternate double and single bonds between the carbon atoms /
delocalised bonding around the ring of carbon atoms

any two ….2×3

(*d*) (*i*) What is observed when B is bubbled into bromine solution as shown in Figure 18? Account for this observation. **6, 3**

decolorises / yellow to colourless

ethyne is unsaturated / ethyne undergoes an addition reaction

first correct …6, second correct …3

(*ii*) Write a balanced equation for the combustion of B in oxygen. **2×3**

$C_2H_2 + 2½O_2 \rightarrow 2CO_2 + H_2O$ / $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

correct formulae …3

balancing correct formulae ...3

Give a common application of this reaction. **3**

(oxyacetylene) welding / cutting metal …3

Question 12
Answer any three parts

Question 12 (*a*)
Car airbags are inflated by the nitrogen gas generated by the rapid decomposition of sodium azide (NaN_3) according to the equation: $2NaN_{3\,(s)} \rightarrow 2Na_{(s)} + 3N_{2\,(g)}$
The sodium produced reacts with potassium nitrate as follows:
$10Na_{(s)} + 2KNO_{3\,(s)} \rightarrow 5Na_2O_{(s)} + K_2O_{(s)} + N_{2\,(g)}$
Calculate

(*i*) the number of moles of sodium azide in an airbag containing 78 g NaN_3, **4, 2**

M_r = 65 …4

$\frac{78}{65}$ = 1.2 (moles) …2

(*ii*) the mass of sodium produced in the first reaction, **2×3**

1.2 moles sodium produced …3

1.2 × 23 = 27.6 (g) …3

(*iii*) the total volume, at s.t.p., of the nitrogen gas produced in both reactions, **2×1, 5**

1.8 moles (nitrogen produced) in first reaction …1

0.12 moles (nitrogen produced) in the second reaction …1

1.92 × 22.4 = 43.008 (litres) …5

Does this nitrogen cause air pollution when it is released into the atmosphere? **1**

no 1

Explain. **2**

doesn't cause global warming or greenhouse effect or acid rain / non-toxic / doesn't damage ozone layer / atmosphere already high percentage nitrogen / etc ...2

Question 12 (*b*)

Refer to the Bronsted-Lowry theory to

(*i*) define an acid, **6**

proton donor …6

[Arrhenius definition unacceptable.]

(*ii*) distinguish between a strong acid and a weak acid. **2×4**

strong acid: good proton donor …4

[allow *'*fully dissociated']

weak acid: poor proton donor …4

[allow *'*partly dissociated']

Copy and complete the following equation, assuming $H_2PO_4^-$ acts as a base.

$HCl_{(aq)}$ + $H_2PO_4^-{}_{(aq)}$ → **2×2**

Cl^- …2

+ H_3PO_4 …2

[charge omitted or incorrect (–1)]

Identify a conjugate pair in your equation. **2**

HCl and Cl^- / $H_2PO_4^-$ and H_3PO_4 …2

[charge omitted or incorrect (–1)]

The venom of an ant, like that shown in Figure 19, contains methanoic acid, a weak acid.
The venom had the same pH as a solution of nitric acid, a strong acid.
Explain why this is possible. **2**

if the strong acid is dilute / if the weak acid is concentrated /
both solutions have the same concentration of H^+ ions …2

Question 12 (*c*)

Define heat of formation. **3×2**

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

from its elements in their standard states …3

[heat required or heat released or heat evolved (−1)]

$$\mathbf{C}_{(s)} + \mathbf{O_2}_{(g)} \rightarrow \mathbf{CO_2}_{(g)} \qquad \Delta H = -393.5 \text{ kJ mol}^{-1}$$

$$\mathbf{H_2}_{(g)} + \mathbf{\frac{1}{2}O_2}_{(g)} \rightarrow \mathbf{H_2O}_{(l)} \qquad \Delta H = -285.8 \text{ kJ mol}^{-1}$$

$$\mathbf{CH_3COOH}_{(l)} + \mathbf{2O_2}_{(g)} \rightarrow \mathbf{2CO_2}_{(g)} + \mathbf{2H_2O}_{(g)} \qquad \Delta H = -875.2 \text{kJ mol}^{-1}$$

Use the heats of reaction above to calculate the heat of formation of ethanoic acid according to the following equation.

$$\mathbf{2C}_{(s)} + \mathbf{2H_2}_{(g)} + \mathbf{O_2}_{(g)} \rightarrow \mathbf{CH_3COOH}_{(l)}$$ **4×3**

$2C_{(s)} + 2O_{2(g)} \rightarrow 2CO_{2(g)}$ $\Delta H = -787.0 \text{ kJ mol}^{-1}$ …3

$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$ $\Delta H = -571.6 \text{ kJ mol}^{-1}$ …3

$2CO_{2(g)} + 2H_2O \rightarrow CH_3COOH_{(l)} + 2O_{2(g)}$ $\Delta H = 875.2 \text{ kJ mol}^{-1}$ …3

$2C_{(s)} + 2H_{2(g)} + O_{2(g)} \rightarrow CH_3COOH_{(l)}$ $\Delta H = -483.4 \text{ kJ mol}^{-1}$ …3

[Equations not essential.]

or

$\Delta H_{\text{combustion}}$ of $CH_3COOH = \Sigma\Delta H_{f(\text{products})} - \Sigma\Delta H_{f(\text{reactants})}$ …3

$-875.2 = -787.0 + -571.6 - \Delta H_f$ of CH_3COOH) …6

(ΔH_f of $CH_3COOH = 875.2 - 787.0 - 571.6 =$) -483.4 kJ mol^{-1} …3

Is this an exothermic or an endothermic reaction? **2**

exothermic …2

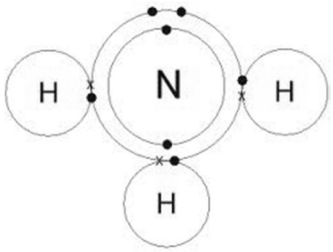
Give a common use for ethanoic acid solutions. **2**

food preservative / flavouring / vinegar / pickling / cleaning / solvent / etc …2

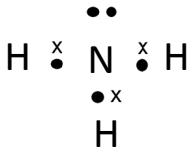
Question 12 (*d*)

***Intra*molecular bonds exist between the atoms *in* a molecule.**

Draw a dot and cross diagram to show the intramolecular bonding in a molecule of ammonia (NH_3). **3**



/



...3

State and explain the shape of the ammonia molecule. **2×3**

pyramidal ...3

[Diagram not acceptable.]

three bond pairs and one lone pair ...3

Define *inter*molecular forces. **3**

bonds or forces that exist between molecules ...3

Name the type of intermolecular force that occurs in

(*i*) ammonia gas, **2**

hydrogen bonds / dipole-dipole interactions or bonds or forces / van der Waals forces or bonds ...2

(*ii*) water, **2**

hydrogen bonds / dipole-dipole interactions or bonds or forces / van der Waals forces or bonds ...2

(*iii*) methane gas. **2**

van der Waals forces or bonds / London dispersion forces ...2

Explain, in terms of intermolecular forces, why NH_3 is very soluble in water. **2×2**

dipole-dipole interactions or hydrogen bonds or van der Waals forces // ...2

formed between (polar covalent) ammonia and water (molecules) ..2

[Allow ...2 for 'like dissolves like' or 'attraction between polar molecules'.]

Blank Page

Blank Page

Blank Page