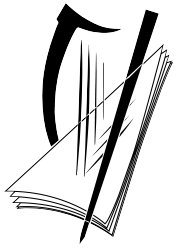


Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2017

Marking Scheme

Physics & Chemistry

Higher Level

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

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

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

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

Future Marking Schemes

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

2017. M38

LEAVING CERTIFICATE EXAMINATION, 2017

PHYSICS AND CHEMISTRY – HIGHER LEVEL

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 the *principle of conservation of momentum.* **2×3**
(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 $m_1u_1 + m_2u_2 =$ …3
is constant //
is equal to total momentum after //
$m_1v_1 + m_2v_2$ / $(m_1 + m_2)v$ …3
[where no external force acts omitted (–1)]

(*b*) Define work. **2×3**
point of application of force / $F \times s$ …3
moves in direction of force / *F* and *s* explained …3
[allow (3) for definition of joule as one newton metre]

(*c*) Figure 1 is a graph of the motion of an animal on a straight, horizontal path.
(*i*) Between which two points of O, A, B and C on the graph is the animal moving at uniform speed towards the starting point? **3**
B and C …3
(*ii*) What is this speed? **3**
$\frac{200}{4} = 50$ {(m per min(ute)} / $\frac{200}{240} = 0.833$ {(m per sec(ond)} …3

(*d*) State Snell's law of refraction. **2×3**
sine of the 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
sine of angle of refraction // sin*r* // constant // = *k* or constant or *n* or μ …3
[reflection instead of refraction (–3)][sines omitted (–3)]

(*e*) What term is used for the splitting up of white light into its constituent colours when passed through a prism? **2×3**
dispersion …3
Why does this phenomenon occur?
colours have different speeds in prism / colours have different refractive indices / colours have different wavelengths / different colours or wavelengths refracted by different amounts (by the prism) …3

(*f*) Ultrasound waves, used in prenatal examinations as shown in Figure 2, are examples of <u>longitudinal waves</u>. Explain the underlined term. **2×3**
(direction of) movement or oscillation or disturbance of particles is parallel …3
to direction (of movement) of wave or energy …3
[information available from labelled diagram]

(*g*) What is the general name of a property that changes measurably as temperature changes? **3**
thermometric …3
What such property is used in a constant volume gas thermometer? **3**
pressure …3

(*h*) Calculate the temperature reading on the Celsius scale when the height of liquid in a liquid-in-glass thermometer is 12 cm; the liquid had heights of 4 cm and 20 cm respectively when placed in ice-water and in steam above boiling water. **2×3**

$\theta = \frac{Y_\theta - Y_0}{Y_{100} - Y_0} \times 100$ …3

$(\theta = \frac{12-4}{20-4} \times 100)$ = 50 (°C) …3

(*i*) What are the fixed points (reference points) on the Kelvin scale of temperature? **2×3**

absolute zero / zero kelvin / –273.15 °C / 0 K …3

triple point of water / 273.16 K / where ice, water and steam co-exist / 0.01 °C …3

[for –273 °C, 273 K, 0 °C apply (–1)]

(*j*) During a thunderstorm, a bolt of lightning resulted in 300 C of charge flowing in a lightning conductor in a time of 2.5×10^{-3} s. Calculate the average current in the conductor. **2×3**

$Q = I \times t$ …3

$(I = \frac{Q}{t} = \frac{300}{2.5 \times 10^{-3}}$ =) 120000 or 1.2×10^5 (A) …3

(*k*) Explain how a fuse protects an electric circuit. **6**

melts or breaks (when current exceeds certain value) …6

(*l*) Copy Figure 3 and sketch the magnetic field pattern around the solenoid when the switch is closed. **2×3**

magnetic field lines correct …3

direction correct …3

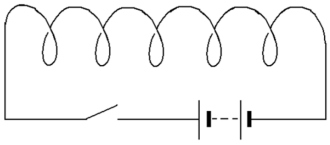


Figure 3

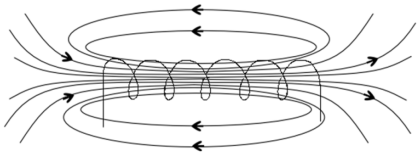


Figure 3 completed

(*m*) What is meant by electromagnetic induction? **2×3**

production of an emf or current …3

when there is (relative) motion between a conductor and a magnetic field …3

(*n*) Why would very high temperatures such as those found in the core of the sun be required to bring about the following nuclear reaction? **2×3**

$_1^2\mathrm{H} + {}_1^3\mathrm{H} \longrightarrow {}_2^4\mathrm{He} + {}_0^1\mathrm{n}$ **+ energy**

to overcome (electrostatic) repulsion of nuclei / to give colliding nuclei very big (kinetic) energies …3

What name is given to this type of nuclear reaction?

fusion …3

(*o*) The energy released in a nuclear reaction is 8.1×10^{-15} J. Calculate the loss in mass involved. **2×3**

$E = m \times c^2$ …3

$(m = \frac{E}{c^2} = \frac{8.1 \times 10^{-15}}{(3 \times 10^8)^2}$ =) 9×10^{-32} (kg) …3

Question 2

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

rate of change of momentum / $\frac{m(v-u)}{t}$ / $\frac{mv-mu}{t}$ / *ma* // *kma* ...3

proportional to applied force / $\propto F$ // = *F* ...3

[*F* = *ma* ....(3)]

Define the unit of force, i.e. the newton. **2×3**

the force that causes a mass one kilogram / *m* = 1 kg ...3

to accelerate by 1 meter per second per second or at 1 m s^{-2} / *a* = 1 m s^{-2} ...3

(*b*) As part of an experiment to investigate Newton's second law, a constant force *F* was applied to a series of different masses *m* and the corresponding accelerations *a* were measured. The following results were obtained.

a (m s^{-2})	0.75	0.86	1.0	1.2	1.5	2.0
m (kg)	4.0	3.5	3.0	2.5	2.0	1.5
1/*m* (kg^{-1})	0.25					

(*i*) Draw a labelled diagram of an apparatus used to obtain these data. **3×3**

trolley on sloped track / trolley on air track ...3

attached by string over a pulley to weights or spring balance ...3

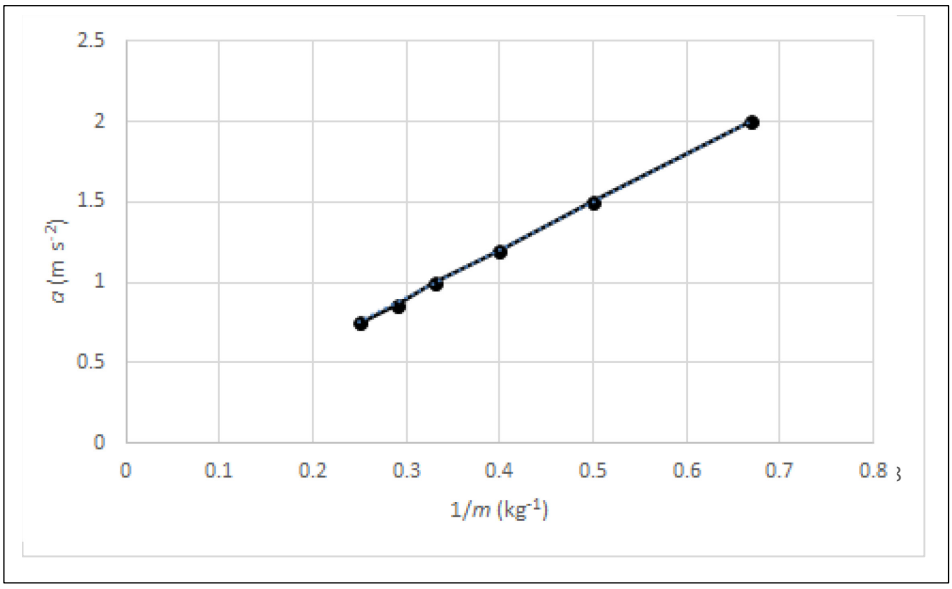
timing using ticker (tape) timer, light gates, powder track, picket fence timer, etc ...3

[no labels...(−3)]

[ticker tape instead of ticker (tape) timer...(−1)][no slope ...(−1)][no pulley ...(−1)]

(*ii*) Calculate the remaining values of 1/*m* and draw a graph of *a* against 1/*m* (*x*-axis). **5×3**

a (m s^{-2})	0.75	0.86	1.0	1.2	1.5	2.0
m (kg)	4.0	3.5	3.0	2.5	2.0	1.5
1/*m* (kg^{-1})	0.25	0.29	0.33	0.4	0.5	0.67



calculate inverse mass for all values …3
[penalise rounding errors once only here]

axes correctly labelled …3
axes drawn with appropriate scales …3
six points correctly plotted …3
straight line through these points ...3
[accept axes reversed]
[maximum (12) marks if graph paper not used]

(*iii*) Use your graph to find the constant force *F* applied to all the masses. **2×3**
$\frac{y_2-y_1}{x_2-x_1} = \frac{1.25}{0.42}$ …3
2.9 – 3.1 newtons or 2.9 – 3.1 N …3
[no unit or incorrect unit (–1)]

(*iv*) What mass would have an acceleration of 1.4 m s^{-2} under this force? **2×3**
$F = ma$ / $m = \frac{F}{a}$ // $\frac{1}{m} = 0.47$ …3
2.14 kg // $\Rightarrow$ m = 2.13 kg …3
[answer may be obtained using $F = ma$ or from graph]
[no unit or incorrect unit (–1)]

(*v*) Explain how your graph verifies Newton's second law. **2, 1**
graph straight line ..2
through origin …1

(*c*) A drone of mass 1.2 kg, shown in Figure 4, is at an altitude of 65 m and has a horizontal velocity in a straight line of 18 m s^{-1}. Its motors are used to control its motion.
Calculate
(*i*) the horizontal force applied by the motors to reduce its velocity to zero in 2 s, **3×3**
$v = u + at$ / $0 = 18 + 2a$ …3
a = –9 (m s^{-2}) / a = 9 (m s^{-2}) …3
($F = ma$ =) 1.2 × 9 = 10.8 N(ewtons) …3
[no unit or incorrect unit (–1)]

(*ii*) the vertical force applied by the motors to prevent it falling, **3**
($F = mg$ =) 1.2 × 9.8 = 11.76 N(ewtons) …3
[no unit or incorrect unit (–1)]

(*iii*) the drone's potential energy due to its position 65 m above the ground. **3**
($E = mgh$ =) 1.2 × 9.8 × 65 = 764.4 J …3
[no unit or incorrect unit (–1)]

Question 3

(*a*) State the laws of reflection of light. **2×3**

angle of incidence is equal to the angle of reflection / $i = r$ …3
incident ray, reflected ray and normal all lie in the same or one plane …3
[refraction instead of reflection …(3), once only][omit to explain *i* and *r* (–1)]

(*b*) Describe, with the aid of a diagram, an experiment to verify one of these laws. **4×3**

plane mirror, ray box or pins, protractor, paper /
two pins to represent incident ray or ray from ray box striking mirror at an angle /
find or draw reflected ray /
draw normal /
measure angles of incidence and reflection /
repeat any four …4×3
[marks may be awarded for information given in diagram]

or

plane mirror, ray box or pins, protractor, paper /
two pins to represent incident ray or ray from ray box striking mirror at an angle along plane of paper /
find reflected ray along plane of paper /
draw normal along plane of paper /
note incident ray, normal and reflected ray all lie on same plane any four …4×3
[marks may be awarded for information given in diagram]

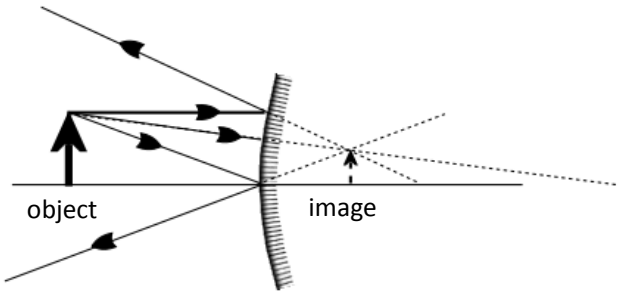
(*c*) Distinguish, in terms of light rays, between a real and a virtual image. **6**

real image formed by the (actual) intersection of light rays /
virtual image formed by the apparent intersection of light rays / virtual image formed light rays appear to meet …6
[real image formed on a screen, virtual image cannot be formed on a screen …(3)]

(*d*) What is the relationship between the focal length *f* and the radius of curvature *c* of a spherical mirror? **3**

half radius of curvature is the focal length / two focal lengths are equal to radius of curvature / $c = 2f$ …3

(*e*) Draw a ray diagram to show image formation in a convex mirror. **3×3**



object in front of convex mirror …3
first rays correctly reflected …3
second ray correctly reflected erect image behind mirror …3

Give two properties of the virtual images formed in a convex mirror. **2×3**

erect / diminished / laterally inverted / located behind the mirror any two …2×3

(*f*) The table below refers to two spherical mirrors A and B.

	Object distance, *u* (cm)	Image distance, *v* (cm)	Magnification, *v*/*u*	Focal length, *f* (cm)	Nature of image
Mirror A	**7**	**–4.2**			**virtual**
Mirror B	**5**		**–6**		**virtual**

Calculate

(*i*) the magnification produced by mirror A, **3**

$(m = \frac{v}{u} = \frac{\pm 4.2}{7} =)$ –0.6 or 0.6 …3

(*ii*) the focal length of mirror A. **2×3**

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} / \frac{1}{f} = \frac{1}{7} + \frac{1}{-4.2} = \frac{-2}{21}$ …3

–10.5 cm …3

[use of +4.2 (–1)]

Calculate

(*iii*) the distance of the image from mirror B, **3**

$(m = \frac{v}{u} / -6 = \frac{v}{5} \Rightarrow$ *v* =) –30 cm / (image distance =) 30 cm …3

(*iv*) the focal length of mirror B. **2×3**

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} / \frac{1}{f} = \frac{1}{5} + \frac{1}{-30} = \frac{1}{6}$ …3

6 cm …3

[use of +30 (–1)]

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

Which of the two mirrors is a convex mirror? **3**

A …3

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

(A has) negative focal length / (A produces) a diminished image /

B produces magnified image / B has a positive focal length …3

Question 4

(*a*) The data obtained in an experiment to verify Boyle's law were used to draw the graph shown in Figure 5.

(*i*) Draw a labelled diagram of an apparatus used to carry out this experiment. **3×3**

fixed volume of gas shown in diagram (in syringe or 'Boyle's law apparatus', etc) …3

scale to read volume shown …3

pressure gauge / device to read pressure …3

[no labels …(−3)]

(*ii*) What measurements were taken using this apparatus? **3**

pressure and volume (of gas) …3

[marks can be obtained from diagram] [(−1) for one only of *p* or *V*]

(*iii*) What two conditions were kept constant during this experiment? **2×3**

temperature …3

mass of gas …3

(*iv*) Use the graph to find the volume of the gas when the pressure was 150 kPa. **2×3**

$\frac{1}{V}$ = 0.05 …3

V = 20 cm^3 …3

[no unit or incorrect unit …(−1)]

(*v*) Boyle's law may be represented by the equation $pV = k$ where k is a constant.

How does the graph verify Boyle's law? **3**

straight line through origin …3

Use the graph to find a value for *k*. **2×3**

$k = m$ / k = slope / $k = \frac{y_2 - y_1}{x_2 - x_1}$ …3

($k = m = \frac{150}{0.05}$) = 3000 kPa cm^3 = 3000000 Pa cm^3 = 3 Pa m^3 …3

[no unit or incorrect unit …(−1)]

(*b*) (*i*) Describe Brownian movement. **3×3**

rapid / random or erratic / zig-zag or straight line any two…2×3

(motion) of small particles or suspended particles or named particles in a gas or in a liquid …3

[example only …(3)]

Explain how it provides evidence for the kinetic theory of gases. **3**

(collisions of suspended particles) indicate the way the gas or liquid molecules (themselves) move …3

(*ii*) What term is used to describe a gas that obeys all the assumptions of the kinetic theory of gases at all temperatures and pressures? **3**

ideal (gas) …3

State two of these assumptions. **2×3**

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

any two…2×3

(*c*) Calculate the number of moles of helium gas in a large foil balloon inflated to a volume of 0.072 m^3 at a pressure of 1.05×10^5 Pa and at room temperature of 20 °C. **3×3**

$PV = nRT$ …3

$1.05 \times 10^5 \times 0.072 = n \times 8.31 \times 293$ …3

n = 3.1(1) (moles) …3

Helium gas escapes from the foil balloon over time.
How many moles of gas were left in the balloon when the inflated volume was reduced to 0.018 m^3 at the same temperature and at a pressure of 1.03×10^5 Pa? **3**

$1.03 \times 10^5 \times 0.018 \div 8.31 \times 293 = 0.76$ (moles) …3

Question 5

(*a*) (*i*) Define 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

[(–1) for each phrase in italics omitted]

(*ii*) State Ohm's law. **2×3**

at constant temperature current is proportional to or $I \propto$ // at constant temperature potential difference is proportional to or $V \propto$ // at constant temperature V = ...3

potential difference or V // current or I // IR …3

[omit at constant temperature …(−1)]

(*iii*) Heating is one possible effect of an electrical current.
What are the other two? **2×3**

chemical ...3

magnetic …3

(*iv*) Classify the following as having a direct current (d.c.) or an alternating current (a.c.) *output*:
battery transformer battery charger
3×2

battery is direct …2

battery charger is direct …2

transformer is alternating …2

(*b*) The USB ports on computers can be used as power 'sources' to supply small electrical currents to operate various gadgets with motors or heating elements or to charge batteries in phones, etc.
A USB supplies a current of 0.5 A at 5 V to the heating element in a mini-hotplate warmer, like that shown in Figure 6.
Calculate

(*i*) the resistance of the heating element, **2×3**

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

($R = \frac{5}{0.5}$ =) 10 Ω …3

[no unit or incorrect unit …(−1)]

(*ii*) the power rating of the heater, **2×3**

$P = VI$ / 5×0.5 …3

(P =) 2.5 W …3

[no unit or incorrect unit …(−1)]

(*ii*) the heat energy supplied when the heater operates for 20 minutes. **2×3**

$H = VIt$ / $H = RI^2t$ $= 5 \times 0.5 \times 20 \times 60$ / $10 \times (0.5 \times 0.5)\ 20 \times 60$ …3

(H =) 3000 J …3

[no unit or incorrect unit …(−1)]

(*c*) Figure 7 shows an apparatus used to demonstrate the principle on which the moving-coil galvanometer is based. An aluminium strip lies loosely between the poles of a magnet as shown. Electric current passes through the aluminium when the switch is closed.

(*i*) What is observed when the switch is closed? **3**

the aluminium foil jumps or moves up (out of the magnet) …3

[(−1) for no direction]

(*ii*) State the principle being demonstrated. **2×3**

current carrying conductor in a magnetic field …3

experiences a force …3

(*d*) A moving-coil galvanometer, that has an internal resistance of 150 Ω and gives a full-scale deflection of 10 mA.

(*i*) Calculate the resistance of the shunt required to enable the galvanometer to measure currents up to 2 A. **2×3**

$I_1R_1 = I_2R_2$ / $0.01 \times 150 = 1.99 \times R_2$ …3

$R_2 = 0.75\ \Omega$ …3

[no unit or incorrect unit …(−1)] [incorrect calculation of I_2…(−1)]

(*ii*) How can a resistor be used to convert the galvanometer into a voltmeter capable of reading voltages up to about 50 V? **6 or 2×3**

multiplier …6

or

(large) resistor / approximately 4850 Ω …3

in series …3

Question 6
Answer any two parts.

Question 6(*a*)
Identify the attractive force that a mass in the Universe exerts on every other mass. **3**
gravitational (force) …3
[allow gravity]

Write an equation for the size of this force in terms of the two masses and the distance between them. **6**
$F = \frac{GMm}{d^2}$ …6
[square omitted …(−3)][sum instead of product …(−3)]
[accept relationship between *g* and *G* / $g = \frac{GM}{d^2}$ for …(3)]

Explain how weight at the surface of the Earth is a specific example of this force. **2×3**
Earth is one mass or particle, object on surface the second mass or particle ….3
radius of Earth is distance between them …3

or

$F = \frac{GMm}{d^2} = W$ / $F = \frac{GMm}{d^2} = mg$ …6

The Hubble Space Telescope, shown in Figure 8, has a mass of 11,110 kg. The radius of the Earth is 6.4×10^6 m.
Calculate
(*i*) the weight the telescope had at the surface of the Earth before it was launched into space, **3**
($W = mg$ = 11110 × 9.8 =) 108878 N(ewtons) …3
[no unit or incorrect unit …(−1)]

(*ii*) the mass of the Earth, **3×3**
$F = \frac{GMm}{d^2} = mg$ / $\frac{GM}{d^2} = g$ …3
$\frac{6.67 \times 10^{-11} M}{(6.4 \times 10^6)^2} = 9.8$ / $\frac{6.67 \times 10^{-11} M \times 11110}{(6.4 \times 10^6)^2} = 108878$ …3
(M =) 6.0×10^{24} kg …3
[no unit or incorrect unit …(−1)]

(*iii*) the acceleration due to Earth's gravity at the orbit of Hubble, 541 km above the surface of the Earth. **2×3**
$\frac{GM}{d^2} = g$ / $\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6 + 541000)^2} = g$ …3
(g =) 8.3 m s^{-2} …3
[no unit or incorrect unit …(−1)]

Question 6(*b*)

What is (*i*) a photon **3**

packet or unit of light energy ...3

[light omitted (−1)][energy omitted (−1)]

(*ii*) the photoelectric effect? **2×3**

release of electrons from (the surface of) a metal ...3

when irradiated with ultraviolet light or light above or of a certain frequency ...3

Describe an experiment to demonstrate the photoelectric effect. **4×3**

freshly sanded piece of metal / Zn plate ...3

electroscope ...3

metal on cap of electroscope illuminated with light source of suitable frequency / uv light ...3

negatively charged electroscope (leaves) collapse / positively charged diverges further / uncharged electroscope (leaves) diverge ...3

[marks available from a clear, labelled diagram]

Monochromatic light of wavelength 375 nm was used to demonstrate the photoelectric effect. Calculate (*iii*) the frequency, **2×3**

$c = f\lambda$ ...3

$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{375 \times 10^{-9}} = 8.0 \times 10^{14}$ Hz ...3

[no unit or incorrect unit …(−1)]

(*iv*) the energy of a photon, of this light. **2×3**

$E = hf$ ..3

$E = 6.626 \times 10^{-34} \times 8.0 \times 10^{14} = 5.30 \times 10^{-19}$ J ...3

[no unit or incorrect unit …(−1)]

Question 6(*c*)

What is radioactivity? **2×3**

(spontaneous) decay of unstable nucleus or nuclei …3

with the emission of radiation /

with the emission of alpha (particles), beta (particles) or gamma (rays) …3

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

time taken for …3

half a sample of a radioactive substance to decay ...3

Krypton–85 is a beta emitter. Write a nuclear equation to represent the beta-decay of Kr–85. **6**

$^{85}_{36}Kr \rightarrow {}^{85}_{37}Rb + {}^{0}_{-1}e$ …6

[one product correct …(3)][accept β or e^-]

After 21.5 years 75% of a sample of Kr–85 has decayed.

Calculate the half-life of the isotope. **2×3**

2 half-lives …3

(21.5 ÷ 2 =) 10.75 years …3

[no unit or incorrect unit …(−1)]

Kr–85 is used industrially to monitor the thickness of paper, plastic and metal. A sample containing Kr–85 is placed on one side of the sheet and a beta-radiation detector on the other.

The thicker the sheet the less intense the stream of beta particles that reaches the detector. Why are alpha-particle sources unsuitable for thickness monitoring in this way? **3**

absorbed too easily / stopped by sheet of paper / low penetration …3

When an alpha-particle source was brought close to the cap of a negatively-charged electroscope as shown in Figure 9, the electroscope lost its charge. Explain why this happened. **6**

air (near cap) ionised …6

[allow (positive) alpha-particles …(3) neutralise charge (on electroscope) ...(3)]

Question 6(*d*)

State Coulomb's Law of force between electrical charges. **6,3 or 9**

force between two (point charges) is proportional to the product (of the size) of the charges …6

and inversely proportional to the square of the distance between them …3

or

$F \propto \frac{Q_1 Q_2}{d^2}$ / $F = k\frac{Q_1 Q_2}{d^2}$ $F = \frac{1}{4\pi\epsilon}\frac{Q_1 Q_2}{d^2}$ …9

[square omitted …(−3)][sum instead of product …(−3)]

***F* is the electrostatic force between two particles, each carrying a positive charge of 4 μC when their centres are a distance 6 cm apart in air.**

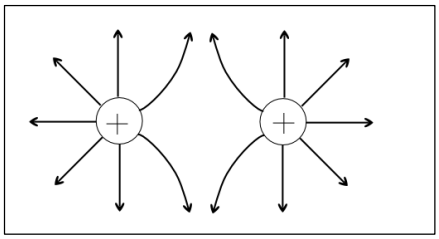
What is the electrostatic force, in terms of *F*, when the distance between them is 3 cm? **3**

4*F* …3

Draw a diagram to show the electrical field around these two positive charges. **2×3**

field lines correct around two positive charges …3

direction correct …3



What is a capacitor? **3**

device that stores (electrical) energy (by separation of charge) …3

[allow device that stores charge]

State two factors on which the capacitance of a parallel-plate capacitor depends. **2×3**

(common) area (of plates) / separation of plates or distance between plates / substance between plates or dielectric any two …2×3

What charge is transferred when a 4 μF parallel-plate capacitor is connected to a 9 V battery? **2×3**

$C = \frac{Q}{V}$ / $Q = CV$ …3

(Q =) $4 \times 10^{-6} \times 9 = 3.6 \times 10^{-5}$ C …3

[no unit or incorrect unit …(−1)]

Question 7
Any eleven parts **11×6**

(*a*) A tripositive ion, M^{3+}, has 10 electrons and 14 neutrons.
What is (*i*) the atomic number, **3**
13 …3
(*ii*) the identity of element M? **3**
Al / aluminium …3

(*b*) The set of quantum numbers {2, 1, 0, +½} identifies an electron in an atom.
(*i*) What main energy level does the electron occupy? **3**
(n =) 2 / 2 / 2^{nd} / second …3
(*ii*) What shape does the orbital occupied by the electron have? **3**
dumbbell …3
[allow diagram of orbital shape including a set of dumbbells]

(*c*) In terms of atomic structure, how is a transition metal defined? **2×3**
partially filled / incomplete …3
d sublevel / *d* subshell …3
[allow …(3) for in d-block (of periodic table)]

(*d*) Figure 10 shows an electron transition from the third shell to the second shell in a hydrogen atom that results in the emission of a photon of red light according to the equation $E_3 - E_2 = hf$.
What do E_3 and *h* represent? **2×3**
E_3: energy of third shell / energy of excited state / higher energy level …3
h: Planck's constant …3
[energy level for E_3 (–1)]

(*e*) Explain why ammonia is very soluble in water but methane is virtually insoluble. **2×3**
ammonia is polar / ammonia forms dipole-dipole interactions or hydrogen bonds with water …3
methane is non-polar / no attraction between methane molecules and water molecules / methane cannot form hydrogen bonds or dipole-dipole interactions …3
[allow …3 for like dissolves like]

(*f*) State
(*i*) the number of electrons in the valence shell of a halogen atom, **3**
7 …3
(*ii*) the valency of chlorine in sodium chloride. **3**
1 …3
[allow +1 or –1]

(*g*) What are the possible shapes of a covalent molecule with the general formula QH_2? **2×3**
v-shaped / bent …3
linear …3
[diagrams acceptable]

(*h*) What is the conjugate base of each of the following species: (*i*) H_3O^+, (*ii*) HCO_3^-? **2×3**
H_2O ...3
CO_3^{2-} ...3
[each charge incorrect (–1)]

(*i*) Explain why boron trifluoride (BF_3) does not have a dipole moment. **6 or 2×3**

centre of positive charge and centre of negative charge coincide / centres of charge coincide …6

or

high degree of …3

symmetry …3

(*j*) Define a mole of a substance in terms of the Avogadro constant. **2×3**

amount of a substance that contains the Avogadro constant or number or 6×10^{23} …3

particles or atoms or molecules or ions …3

[allow other correct definitions of a mole that do not refer to Avogadro constant …(3)]

(*k*) Titanium metal, used in the type of replacement joint shown in Figure 11, can be extracted from an ore called ilmenite ($FeTiO_3$). Calculate the percentage by mass of oxygen in this ore.
(O = 16, Ti = 48, Fe = 56) **2×3**

(M_r =) 152 ...3

(% oxygen =) $\frac{3 \times 16}{152} \times 100$ = 31.6% ...3

(*l*) When 0.8 g of sodium hydroxide (NaOH) dissolves in a large quantity of water, 890 J of energy are released. Calculate the heat of solution of sodium hydroxide.
(H = 1, O = 16, Na = 23) **2×3**

(0.8 ÷ 40 =) 0.02 (moles) / (0.8 ÷ 40 =) 1/50 (moles) or 0.02 (moles) ...3

(–890 ÷ 0.02 = / –890 × 50 =) –44.5 (kJ mol^{-1}) / –44500 (J mol^{-1}) ...3

[positive heat of solution …(−1)]

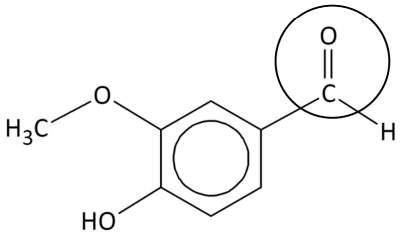
(*m*) Distinguish between aliphatic and aromatic organic compounds. **6**

aliphatic (compounds) do not contain a benzene ring / aromatic (compounds) contain a benzene ring …6

(*n*) Copy Figure 12, the structure of vanillin, which is the main ingredient in the flavouring vanilla, into your answer book.

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

…3



(*ii*) What is the molecular formula of vanillin? **3**

$C_8H_8O_3$ …3

(*o*) Write a balanced equation for the complete combustion of benzene (C_6H_6) in oxygen. **2×3**

$C_6H_6 + 7½O_2 \rightarrow 6CO_2 + 3H_2O$ / $2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O$

formulae …3

balanced ...3

Question 8

(*a*) Distinguish between mass number and relative atomic mass. **3, 3×2**

mass number: number of protons and neutrons (in an atom) …3

relative atomic mass:
taking isotope abundances into account / weighted …2
average mass of an atom of an element /average of mass numbers …2
compared to $1/12^{th}$ carbon-12 …2
[average omitted (–1)] [$1/12^{th}$ omitted (–1)]

Atoms of the element boron that have either 5 or 6 neutrons in their nuclei exist in nature.
State the mass number of each of these two different kinds of boron atom. **2×3**
10 …3
11 …3

Explain why both types of boron atom have the same chemical properties. **3**
same number of electrons / chemical properties depend on number of electrons …3

What term is used to describe atoms of the same element that have different numbers of neutrons? **3**
isotopes …3

19.9% of the atoms in a sample of boron have 5 neutrons and 80.1% of the atoms in the sample have 6 neutrons.
Calculate the relative atomic mass of boron. **3×3**
$19.9 \times 10 = 199$ …3
$80.1 \times 11 = 881.1$ …3
$199 + 881.1 = 1080.1 \Rightarrow A_r = 10.801$ …3
[allow 10.81 from *Formulae and Tables* booklet …(3)][(–3) for each atomic number used]

(*b*) 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
[omit measure of …(–1)]

Use electronegativity values to predict the type of bonding in (*i*) CaO, (*ii*) HBr. **2×3**
CaO: ionic (3.44 – 1.00 = 2.44) …3
HBr: polar (covalent) (2.96 – 2.2 = 0.76) …3
[covalent (–1)]
[allow …(3) for two correct electronegativity differences with no conclusion or incorrect conclusion]

(*c*) The table below shows the electronegativity value and the atomic radius for each of the elements in the second period of the Periodic Table, excluding neon.

Element	Li	Be	B	C	N	O	F
Atomic number (*Z*)	3	4	5	6	7	8	9
Electronegativity	0.98	1.57	2.04	2.55	3.04	3.44	3.98
Atomic radius (pm)	123	89	81	77	70	66	64

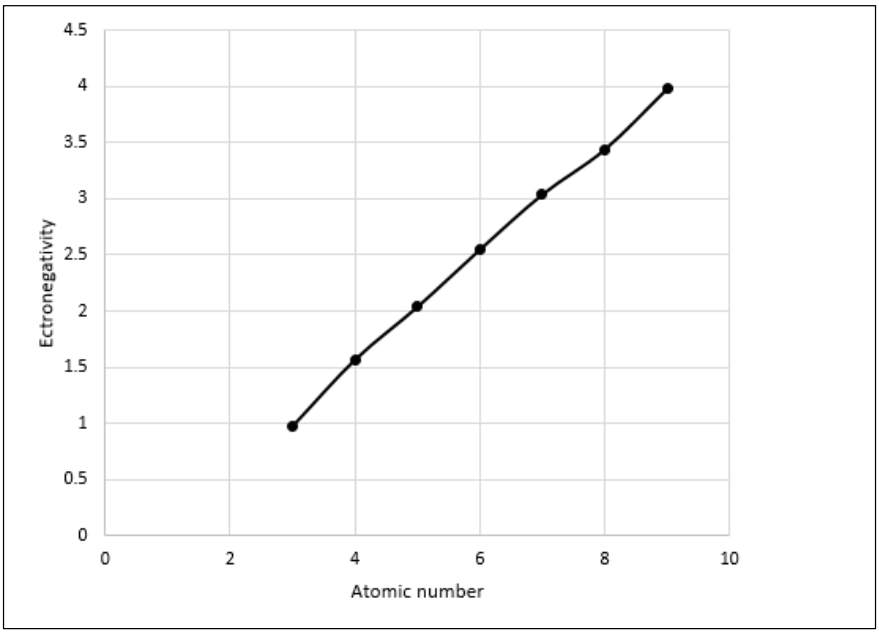
Draw a graph to show the relationship between electronegativity value and atomic number (*Z*) for elements 3 to 9. **3×3**

both axes labelled (electronegativity, atomic number) and scaled correctly …3

7 points plotted correctly …3

points joined (not necessarily with smooth line) …3

[bar chart acceptable]



Why is there a decrease in atomic radius from element 3 to element 9? **2×3**

nuclear charge increasing …3

bigger attraction for (outer) electrons / pulls (outer) electrons in more or closer to nucleus …3

Explain (*i*) how, and (*ii*) why, electronegativity values across the second period are influenced by atomic radius. **2×3**

as radius decreases electronegativity values increase / electronegativity values decrease for larger atomic radii …3

smaller attraction (of nucleus) for shared pair when radius is large / shared pair farther away (from nucleus) and means smaller attraction …3

Why do the electronegativity values of the alkali metals decrease as their atomic numbers increase? **3**

increasing atomic radius / increasing screening effect …3

Question 9

Propanoic acid (C_2H_5COOH) is a <u>weak acid</u> and it is <u>monoprotic</u>. It has antibacterial and antifungal properties and can be used as a food preservative.

A solution of propanoic acid was titrated against 25.0 cm^3 portions of a <u>standard solution</u> of 0.10 M sodium hydroxide (NaOH) using a suitable indicator.

The balanced equaton for the reaction is:

$$C_2H_5COOH + NaOH \rightarrow C_2H_5COONa + H_2O$$

(*a*) Explain the underlined terms. **<u>6, 2×3</u>**

weak acid: not fully dissociated / slightly dissociated / poor proton donor

monoprotic: monobasic / one acidic hydrogen (per molecule) / donates one proton / donates one H^+ (ion)

standard solution: solution of (exactly) known concentration

(first correct….6, second correct…3, third correct …3)

(*b*) Identify the hazard symbol in Figure 13 used on bottles of acids and bases. **<u>3</u>**

corrosive / burns skin or materials …3

[allow harmful, irritant …(3)]

State one precaution taken to handle these solutions safely. **<u>3</u>**

wear gloves, wear eye protection, etc …3

(*c*) The equipment in Figure 14 is used to deliver 25.0 cm^3 of the NaOH solution into a titration flask.

Name X. **<u>3</u>**

pipette ...3

Describe how X was rinsed before use. **<u>2×3</u>**

rinse with deionised or distilled water …3

rinse with sodium hydroxide solution / rinse with solution it is to deliver …3

What is the advantage of attaching a suction device like Y to the top of X? **<u>3</u>**

safety / to avoid swallowing (solution in pipette) / easier to fill …3

(*d*) Name a suitable indicator for this titration. **<u>3</u>**

phenolphthalein …3

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

strong base / weak acid (titration) …3

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

pink/red/purple ...3

colourless ...3

[allow max (3) if colours are reversed]

(*e*) On average, 19.55 cm^3 of propanoic acid solution was required to neutralise 25.0 cm^3 of 0.10 M NaOH solution.
Calculate the concentration of propanoic acid in
(*i*) moles per litre, **2×3**

$\frac{V_1 \times M_1}{n_1} = \frac{V_2 \times M_2}{n_{12}} / \frac{19.55 \times M_1}{1} = \frac{25 \times 0.1}{1} /$

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

(M_1) = 0.13 (M) [0.1279 – 0.13 M] …3

or

moles of NaOH used = $\frac{25 \times 0.1}{1000}$ = 0.0025 …3

0.0025 moles of propanoic acid in 19.55 cm^3 $\Rightarrow \frac{0.0025 \times 1000}{19.55}$ = 0.13 (moles / L) [0.1279 – 0.13 M] …3

(*ii*) grams per litre. **2×3**

(M_r of C_2H_5COOH =) 74 …3

0.13 × 74 = 9.62 (g / L) [9.46 – 9.62 g / L] …3

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

pH = – log [H^+] …3

Calculate the pH of the 0.10 M NaOH solution. **3×3**

(pOH =) –log [OH^-] / –log (0.1) …3

(pOH =) 1 …3

(pH =) 13 …3

Question 10

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

reduction is the gain of electrons …3

Identify the reducing agent in each of the following reactions. **2×3**

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

$$Al_2O_3 + 3Mg \rightarrow 3MgO + 2Al$$

CO /carbon monoxide …3

Mg / magnesium …3

(*b*) Arrange the following metals in order of *decreasing* ease of oxidation. **6**

gold magnesium iron aluminium copper

magnesium, aluminium, iron, copper, gold 6

[allow reverse order …(3); allow magnesium first and gold last …(3]

(*c*) What is a sacrificial anode? **3**

use of metal (easily oxidised or higher up the electrochemical series) to protect another …3

Give an example of the use of a sacrificial anode. **3**

use magnesium or aluminium to protect iron pipes or boats, etc ..3

(*d*) What is electrolysis? **3**

using electricity to bring about a chemical reaction …3

[example acceptable]

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

mass or volume or amount of substance liberated at, formed on or deposited on an electrode (during electrolysis) / m …3

is proportional to the (quantity of) charge that passes (through the electrolyte) / is proportional to the size of current and time for which it passes (through the electrolyte) / $\propto Q$ / $\propto It$ / = zIt …3

[quantity of electricity (–1)]

(*e*) Figure 15 shows an arrangement for the electrolysis of molten lithium chloride (LiCl) using graphite electrodes.

(*i*) Which of the electrodes X or Y is the anode? **3**

X …3

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

X / positive / left hand electrode /anode …3

Justify your answer. **3**

anode is the positive electrode / loss of electrons at positive electrode / chloride ions lose electrons at anode / oxidation occurs at the anode …3

(*iii*) Write a balanced equation for the oxidation reaction. **2×3**

Cl^- // $2Cl^-$ …3

$(\rightarrow Cl + e^-) \rightarrow \frac{1}{2}Cl_2 + e^-$ // $(\rightarrow 2Cl + 2e^-) \rightarrow Cl_2 + 2e^-$ …3

(*iv*) Suggest a reason why this electrolysis should only be carried out in a fume cupboard. **3**

chlorine fumes toxic …3

(*iv*) Explain why the bulb does not light until the lithium chloride has been heated strongly for several minutes using the Bunsen burner. **2×3**

ions free to move // ions not free to move …3

only when lithium chloride molten // in solid state …3

(*v*) Calculate the mass of metal produced in this electrolysis when a current of 3 A flows for 24 minutes. **4×3**

$Q = It = 3 \times 60 \times 24 = 4320$ (C) ...3

$4320 \div 96485.3383 = 0.045$ (moles electrons or moles lithium) / $4320 \div 1.6 \times 10^{-19}$ = (electrons or lithium atoms) …3

$A_r = 7$ ...3

$7 \times 0.045 = 0.3 - 0.32$ (g) / $\frac{2.7 \times 10^{22}}{6.0 \times 10^{23}} \times 7 = 0.3 - 0.32$ (g) …3

Question 11

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

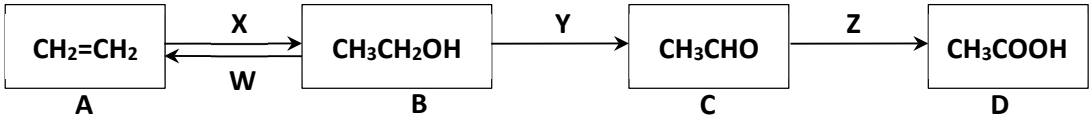


Figure 16

(*a*) (*i*) Name the compounds A, B, C and D. **3×4**

(A =) ethene …3
(B =) ethanol …3
(C =) ethanal …3
(D =) ethanoic acid …3

(*ii*) A is a hydrocarbon and is unsaturated. Explain the underlined terms. **2×3, 6**

hydrocarbon: contains carbon and hydrogen …3
only …3
unsaturated: contains (at least one) double or triple bond (between a pair of carbon atoms) …6

(*iii*) Describe how to test a sample of A for unsaturation. **6, 3**

add bromine solution / add acidified (potassium) permanganate (solution) …6
decolourises …3
[acidified omitted (–3)]

(*iv*) To what homologous series does B belong? **3**

alcohol …3

(*v*) Describe a chemical test you would carry out on a sample of C to confirm that it is an aldehyde. **2×3**

add Fehling's reagent // add Tollens reagent or ammonical silver nitrate and heat …3
blue to red // colourless to silver mirror …3
[(–1) for heat omitted]

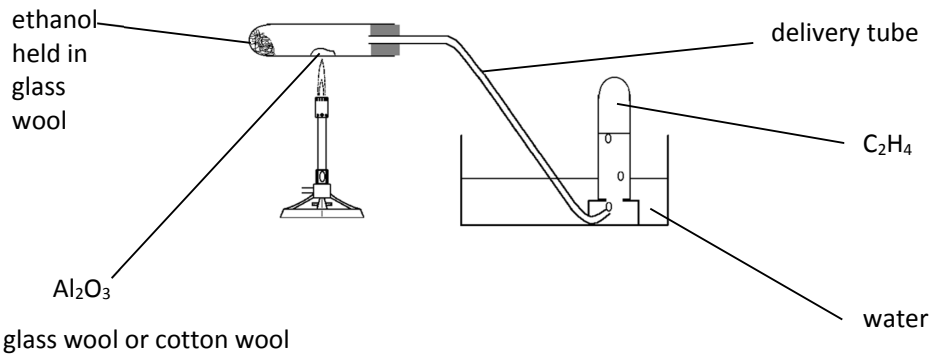
(*b*) (*i*) Which one of the conversions W, X, Y and Z is an addition reaction? **3**

X …3

(*ii*) Classify any one of the conversions W, X, Y and Z as an oxidation reaction. **3**

Y / Z …3

(*c*) Draw a labelled diagram to show the arrangement of apparatus and chemicals you would use to prepare and collect A. **3×3**

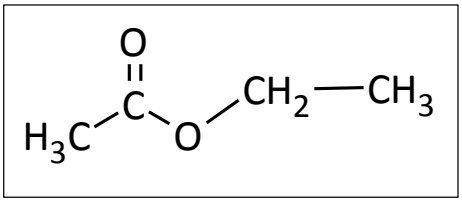


ethanol or B held in glass wool or cotton wool …3
aluminium oxide in correct position in test-tube …3
bunsen burner heating aluminium oxide …3
delivery tube and collection of gas over water …3
any three …3×3

[no labels ….max (3)]

(*d*) Which two of the compounds in the scheme react together to form an ester? **3×3**
ethanol / B …3
ethanoic acid / D …3

Give the name of this ester or draw its structure.
ethyl ethanoate / correct ester structure …3



Question 12
Answer any three parts.

Question 12(*a*)
A coal contains 2.5% sulfur by mass. When the coal is burned at a power plant the sulfur in it is converted to gaseous sulfur dioxide. Scrubbers in the power plant chimneys act as filters, continuously removing this sulfur dioxide from emission gases by reaction with calcium carbonate. These reactions are described by the following balanced equations.

$$S_{(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)}$$
$$CaCO_{3\,(s)} + SO_{2\,(g)} \rightarrow CaSO_{3\,(s)} + CO_{2\,(g)}$$

(*i*) Classify sulfur dioxide as an amphoteric, an acidic, a basic or a neutral oxide. **2**
acidic …2

What environmental problem would result from the release of SO_2 into the atmosphere? **2**
acid rain / asthma or breathing difficulties, etc / damage to trees or forests / damage to buildings or metals …2

(*ii*) What mass of sulphur is in 5.12×10^6 kg of this coal, burned in one day at the power plant? **3**
$\frac{2.5}{100} \times 5.12 \times 10^6 = 128000$ (kg) / 1.28×10^8 (g) ...3

How many moles of SO_2 are produced from this sulphur? **2×3**
$A_r = 32$ ...3
$\frac{128000000}{32} = 4\,000\,000 = 4 \times 10^6$ (moles) ...3
[4000 (moles) …3]

What volume of oxygen gas reacts with this sulphur at s.t.p.? **3**
$4 \times 10^6 \times 22.4 = 8.96 \times 10^7$ litres …3
[no unit or incorrect unit …(−1)]

What mass of $CaSO_3$ is produced per day by the scrubbers? **2×3**
$M_r = 120$ …3
$120 \times 4 \times 10^6 = 480\,000\,000$ g or 480 000 kg …3
[no unit or incorrect unit …(−1)]

Question 12(*b*)

Define an atomic orbital. **2×3**

region in space (around the nucleus of an atom) …3

where the probability of finding an electron is high …3

Write the *s, p* electronic configuration of (*i*) a silicon atom, **2×3**

$1s^2\ 2s^2\ 2p^6$ ...3

$3s^2\ 3p^2$ / $3s^2\ 3p_x^1\ 3p_y^1$ ...3

(*ii*) a phosphorus atom. **3**

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

[allow superscripts instead of subscripts and vice versa]]

Which electron configuration is more stable? **3**

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^1\ 3p_y^1\ 3p_z^1$ / second one / phosphorus / P …3

Explain your answer. **2**

half-full subshell (more) stable …2

What species is represented by the electron configuration $[1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6]^{2+}$? **2**

Ca^{2+} / calcium ion …2

Question 12(*c*)

Silicon and diamond have similar crystalline structures.

What type of crystal structure is present in diamond? **3**

atomic / covalent / macromolecular …3

Explain in terms of its bonding

(*i*) the hardness of a diamond, **3**

(each carbon atom bonded to four neighbouring atoms by) strong covalent bonds …3

(*ii*) diamond's inability to conduct electricity. **4**

electrons (in covalent bonds) not free to move (throughout solid) …4

Figure 17 shows table salt (NaCl), an ionic crystal, and rock candy (sugar), a molecular crystal.

What are the bonding forces

(*iii*) in an ionic crystal, **4**

ionic bonds / electrostatic attractions …4

(*iv*) that hold a molecular crystal together? **3**

intermolecular bonds / van der Waals / hydrogen bonds / dipole-dipole interactions …3

Explain why molecular crystals usually have lower melting points than ionic crystals. **3**

binding forces in molecular crystals weaker than ionic bonds /
intermoleclar bonds or van der Waals forces or dipole-dipole interactions weaker or more easily broken than ionic bonds …3

What type of crystal is characterised by a solid having a lustre and a very high mobility of electrons throughout its structure? **2**

metallic …2

Question 12(*d*)

Define heat of formation. **2×3**

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

from its elements in their standard states …3

[heat required or heat released (−1)] [omit standard states (−1)]

Use the following heat of formation data

$$\mathbf{\tfrac{1}{2}H_{2\,(g)} + \tfrac{1}{2}Cl_{2\,(g)} \rightarrow HCl_{(g)} \quad \Delta H = -92.3\ kJ\ mol^{-1}}$$

$$\mathbf{C_{(s)} + 2H_{2\,(g)} \rightarrow CH_{4\,(g)} \quad \Delta H = -74.6\ kJ\ mol^{-1}}$$

$$\mathbf{C_{(s)} + 1\tfrac{1}{2}H_{2\,(g)} + \tfrac{1}{2}Cl_{2\,(g)} \rightarrow CH_3Cl_{(g)} \quad \Delta H = -81.9\ kJ\ mol^{-1}}$$

to calculate Δ*H* for the substitution reaction of methane with chlorine according to the following equation.

$$\mathbf{CH_{4\,(g)} + Cl_{2\,(g)} \rightarrow CH_3Cl_{(g)} + HCl_{(g)}} \qquad \textbf{4×3}$$

$$CH_{4\,(g)} \rightarrow C_{(s)} + 2H_{2\,(g)} \quad \Delta H = 74.6\ kJ\ mol^{-1} \quad \text{...3}$$

$$C_{(s)} + 1\tfrac{1}{2}H_{2\,(g)} + \tfrac{1}{2}Cl_{2\,(g)} \rightarrow CH_3Cl_{(g)} \quad \Delta H = -81.9\ kJ\ mol^{-1} \quad \text{...3}$$

$$\tfrac{1}{2}H_{2\,(g)} + \tfrac{1}{2}Cl_{2\,(g} \rightarrow HCl_{(g)} \quad \Delta H = -92.3\ kJ\ mol^{-1} \quad \text{...3}$$

$$CH_{4\,(g)} + Cl_{2\,(g)} \rightarrow CH_3Cl_{(g)} + HCl_{(g)} \quad \Delta H = -99.6\ kJ\ mol^{-1} \quad \text{...3}$$

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

exothermic …2

Why is ultraviolet light needed for this reaction to happen? **2**

to start the reaction / to break the bond in chlorine / to make free radicals …2

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