Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2025

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 for the written examination, 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. Where incorrect terminology is used or where part of the candidate's answer contradicts another part, the marks may not be awarded. Cancellation may apply when a candidate gives more than the required number of responses, or a list of correct and incorrect answers.

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

4. The descriptions, methods and definitions in the scheme are **not** exhaustive and alternative valid answers are acceptable.

5. The detail required in any answer is determined by the context and manner in which the question is asked, and also by the number of marks assigned to the answer in the examination paper. Therefore, in any instance, it may vary from year to year. Material that is bracketed is not required in that year.

6. Each time an arithmetical slip occurs in a calculation, one mark is deducted ; this also applies to inappropriate or incorrect rounding of numerical answers.

7. For omission of appropriate units (or for incorrect units) in final answers, one mark is deducted, unless otherwise indicated.

8. 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 75% or less of the total mark available (i.e. 300 marks or less). 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. See below for when a candidate is awarded more than 300 marks.

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

1. Any eleven parts

(*a*) State Newton's first law of motion.

a body remains at rest / a constant velocity

unless acted on by a force **(4 + 2)**

(*b*) Calculate the work done by a mass of 50 kg when its velocity changes from 15 m s^{-1} to 25 m s^{-1}.

$\frac{1}{2}$ (50)($25^2 - 15^2$) / correct formula implied

10000 (J) **(4 + 2)**

(*c*) Define the SI unit of force, the Newton (N).

the force that cause a mass of 1 Kg

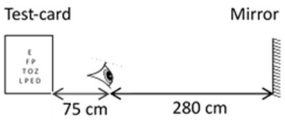
to accelerate by 1 ms^{-2} **(4 + 2)**

(*d*) Calculate the gravitational force exerted by the Sun on the Earth. (mass of Sun = 1.989×10^{30} kg, mass of Earth = 5.972×10^{24} kg, distance between Sun and Earth = 1.496×10^{11} m)

$F = \frac{Gm_1m_2}{d^2}$ / $F = \frac{6.6742\times10^{-11}(1.989\times10^{30})(5.972\times10^{24})}{(1.496\times10^{11})^2}$

3.5×10^{22}(N) **(4 + 2)**

(*e*) An optician places a test card 75 cm behind a patient who is 280 cm from a plane mirror, as shown. Calculate the distance from the patient to the image of the card.



75 + 280 = 355 (cm)

280 + 355 = 635 (cm) **(4 + 2)**

(*f*) Images formed by mirrors show <u>lateral inversion</u>. Explain the underlined term.

interchange / flipping of the left and right side of object when looking at image **(6)**

(*g*) State a property of gas particles affected by a change in temperature.

kinetic energy / velocity **(6)**

(*h*) State the conditions of pressure and temperature under which the behaviour of a real gas approximates to that of the ideal gas.

low pressure

high temperature **(4 + 2)**

(*i*) Write an expression for the relationship between temperature on the Kelvin scale, *T*, and temperature on the Celsius scale, θ.

T(K) = θ (°C) +

273.15 **(4 + 2)**

(*j*) State two ways in which light can be dispersed.

diffraction grating / prism etc. **(4 + 2)**

(*k*) An interference pattern can be observed using Young's slits. Describe how the pattern observed on the screen changes when the distance between the slits is decreased.

distance (between fringes) increases **(6)**

(*l*) Explain why metals are good conductors of electricity.

electrons are free to move **(6)**

(*m*) State one advantage of using (*i*) high voltages (*ii*) alternating current in the long-distance transmission of electrical energy.

(i) less loss of energy as heat

(ii) can be stepped up or down easily **(4 + 2)**

(*n*) State the principle on which the moving coil galvanometer is based.

a conductor carrying a current in a magnetic field

experiences a force **(4 + 2)**

(*o*) The force between two identical point charges 5 cm apart is 2.5×10^{-4} N. What would the effect on the force be when the distance between the charges is increased to 10 cm?

$F \propto \frac{1}{d^2}$ / 6.25×10^{-5} /decreases (by a factor of 4) **(6)**

(*p*) Explain why neutrons are the most effective subatomic particle for bombarding nuclei.

no charge

not repelled by positive nucleus **(4 + 2)**

(*q*) What is meant by the term radioactivity?

(spontaneous) disintegration of a nucleus

with the release of radiation **(4 + 2)**

(*r*) Calculate the energy released when 0.0075 % of the mass of 1 kg of natural uranium is converted into energy.

$E = mc^2$ / $E = 0.000075\ (2.997 \times 10^8)^2$

$E = 6.74 \times 10^{12}$ (J) **(4 + 2)**

2. (*a*) (*i*) What is meant by momentum?

product of mass and velocity / formula (and notation)

(*ii*) State the principle of conservation of momentum.

in a closed system

total momentum before equal total momentum after

/ formula (and notation) **(5 + 2 + 2)**

(*b*) An experiment was carried out to verify the principle of conservation of momentum. Body **A** of mass 310 g travelled 41 cm in 0.5 s before colliding with body **B** of mass 230 g, which was at rest. After collision the two masses moved on together with a common constant velocity of 0.471 m s^{-1}.

(*i*) Draw a labelled diagram of an arrangement of apparatus that can be used to verify the principle of conservation of momentum.

labelled diagram

runway/air-track with two trolleys/riders

means of getting trolleys to stick to each other

means of measuring distance and time **[*any 3]*** **(8 + 2 + 2)**

The effects of the external forces, gravity and friction, are minimised in this experiment.

(*ii*) State how the effects of both gravity and friction can be minimised.

Gravity: level track

Friction: Air cushion / polish the track / track sloped **(4 + 2)**

(*iii*) Calculate the initial velocity of body **A**.

v = s/t / v = 0.41/0.5

v = 0.82 m s^{-1} **(4 + 2)**

(*iv*) Calculate the total momentum before the collision.

(0.310)(0.82) + (0.230)(0)

0.2542 kg m s^{-1} **(4 + 2)**

(*v*) Calculate the total momentum after the collision.

(0.310 + 0.230)(0.471)

0.2543 kg m s^{-1} **(4 + 2)**

(*vi*) Use the data to show that this experiment verifies the principle of conservation of momentum.

0.2542 kg m s^{-1} ≈ 0.2543 kg m s^{-1} / momentum before equals momentum after

momentum is conserved **(4 + 2)**

(*c*) (*i*) What is meant by the kinetic energy of an object?

energy due to motion / formula (and notation) **(8)**

(*ii*) Calculate the kinetic energy lost during the collision.

$\Delta E = \frac{1}{2} m{v_1}^2 - \frac{1}{2} m{v_2}^2$ **/** $\Delta E = 0.1042 - 0.0599$ **(2)**

$\Delta E = 0.0443$ **J** **(2)**

(*iii*) Account for the loss in kinetic energy during the collision.

sound/heat/vibration **(3)**

3. (*a*) (*i*) State Snell's law.

sin *i* is proportional / $\frac{Sin\ i}{Sin\ r}$ (3)

to sin *r* / = n (3)

Diamonds are cut so as to 'sparkle'. This is due to the phenomenon of total internal reflection within the gemstone. The critical angle for diamond is 24.4°.

(*ii*) What is meant by the critical angle of a material?

angle of incidence (in the denser medium)

angle of refraction is 90° (4 + 2)

(*iii*) State the two conditions necessary for total internal reflection of light to occur.

light must be travelling from a more to less dense medium

angle of incidence must be greater than the critical angle (4 + 2)

(*iv*) Calculate the refractive index of diamond.

$\frac{1}{\text{Sin C}}$ **= n /** $\frac{1}{0.42}$ **= n**

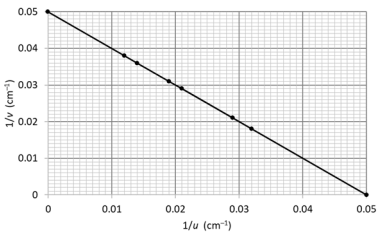
2.42 = n (4 + 2)

(*v*) Draw a labelled diagram to show how a light beam can travel along an optic fibre by means of total internal reflection.

ray moving with angle of incidence greater than critical angle

less dense cladding / denser core labelled (4 + 2)

(*b*) In an experiment to determine the focal length of a convex lens, object distance (*u*) and image distance (*v*) are measured and the results are displayed on a graph.



(*i*) Use the graph above to determine the focal length of the lens. Note: only work written in your answerbook can be awarded marks.

lens formula (2)

correct value for 1/u or 1/v from graph inserted into lens formula (2)

f = 20 cm (2)

(*ii*) Calculate the magnification of the image when the object is placed 25 cm from the lens.

value for v (3)

magnification formula (3)

m = 4 (3)

(*iii*) Does the radius of curvature of a convex lens increase or decrease with increasing focal length? Justify your answer.

increases

reference to C = 2f (4 + 2)

(*c*) An object is placed 20 cm from a concave lens of focal length 5 cm.

(*i*) Calculate the image distance, *v*.

$-\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$ / $-\frac{1}{5}=\frac{1}{20}+\frac{1}{v}$ **(3)**

V=(–) 4 cm **(3)**

(*ii*) Draw a ray diagram to show the formation of a virtual image by a concave lens.

rays approaching a lens **(5)**

rays refracted correctly by lens **(2)**

intersection of ray to form virtual image **(2)**

[allow a maximum of 5 marks if convex lens used]

4. (*a*) (*i*) State Boyle's law.

at constant temperature the pressure of a fixed mass of gas
is inversely proportional to the volume **(4 + 2)**
[allow 4 marks for $P \propto \frac{1}{V}$]

(*ii*) Draw a labelled diagram of an apparatus which can be used to verify Boyle's law.

fixed mass gas labelled
method of changing volume
method of reading pressure **[*any two correct*]** **(5 + 4)**

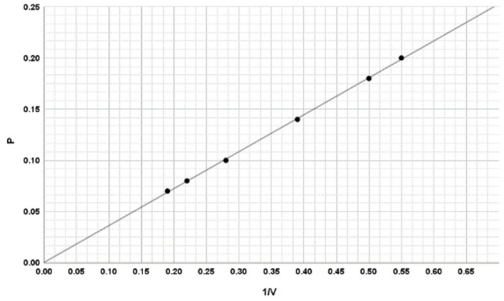
An experiment to verify Boyle's law was carried out using 0.15 moles of a gas at a temperature, *T* and the following data obtained.

V ($\times 10^{-3}$ m^3)	1.81	2.01	2.58	3.61	4.48	5.16
P ($\times 10^6$ Pa)	0.20	0.18	0.14	0.10	0.08	0.07

(*iii*) Using the recorded data, draw a suitable graph on graph paper showing the relationship between the pressure and volume of a gas.

1/p **(× 10^{-6} Pa)**	**5.0**	**5.5**	**7.1**	**10**	**12.5**	**14.3**
1/V **(× 10^3 m^{-3})**	**0.55**	**0.50**	**0.39**	**0.28**	**0.22**	**0.19**

/



values for 1/p or 1/v **(3)**
Labelled axis **(3)**
correct points plotted **(6 × 1)**
line of best fit **(3)**

(*iv*) Explain how your graph verifies Boyle's law.

graph shows a straight line through the origin **(3)**

(*v*) Use the slope of the graph to find temperature, *T*.

pV =nRT / slope formula
slope =nRT / 363.63 = nRT
291.6 K = T **(5 + 2 + 2)**

(*b*) (*i*) Distinguish between heat and temperature.

heat is a form of energy / temperature is a measure of hotness

(*ii*) Define the term absolute zero.

lowest temperature theoretically possible / movement of particles has stopped

(*iii*) State the exact value of absolute zero on the Celsius scale.

– 273.15 (°C)

(*iv*) What is meant by the triple point of water?

the temperature at which ice, water and water vapor coexist (at a certain pressure)
(6 + 6 + 3 + 3)

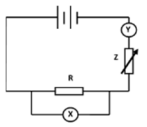
The pressure recorded using a constant volume gas thermometer at the freezing point of water is 9.5 kPa. The pressure at the boiling point of water is 13 kPa. The pressure at room temperature is 10.2 kPa.

(*v*) Calculate the temperature of the room.

$$\frac{t}{100} = \frac{x_t - x_0}{x_{100} - x_0} \;/\; \frac{t}{100} = \frac{10.2 - 9.5}{13.0 - 9.5}$$

t = 20 (°C) **(4+2)**

5. (*a*) Using the circuit shown below, a constant current, *I*, was passed through different resistors with resistance *R*.



(*i*) State Ohm's law.

current in a conductor is proportional to potential difference // I ∝ V **(4)**

at constant temperature // at constant temperature **(2)**

(*ii*) Identify the meters labelled X and Y.

X = voltmeter

Y = ammeter **(4 + 2)**

Z is a variable resistor.

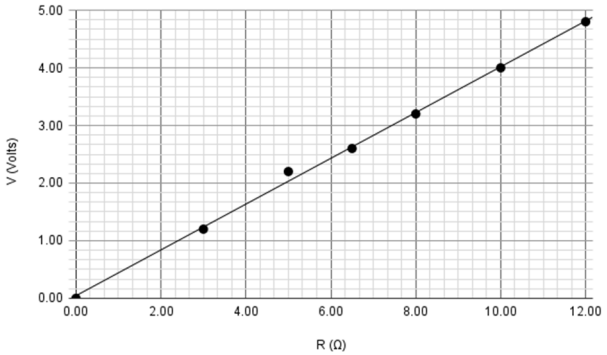
(*iii*) State the function of Z in the circuit.

controls the rate of flow of charge **(3)**

The potential difference, *V*, across each resistor was measured and the data recorded.

R (Ω)	0	3	5	6.5	8	10	12
V (Volts)	0	1.2	2.2	2.6	3.2	4.0	4.8

(*iv*) Plot a graph, on graph paper, of *R* versus *V*.



axis labelled correctly **(3)**

points plotted correctly **(6 × 1)**

straight line of best fit **(3)**

(*v*) Explain how your graph verifies Ohm's law.

straight line through the origin **(3)**

(*vi*) Use your graph to find the constant current, *I*, flowing in each resistor.

slope

I = 0.4 A **(4 + 2)**

One of the data points is inconsistent with the other data points.

(*vii*) Identify the point.

(5 , 2.2) / indicated on graph **(4)**

(*viii*) Suggest, with reference to Ohm's law, a reason for the inconsistency.

temperature not kept constant **(2)**

(*b*) (*i*) Define electrical power.

rate at which work is done or electrical energy is transferred in an electrical circuit / equation (with notation) **(4)**

(*ii*) Define the unit of electrical power, the watt.

1 watt = 1 joule per second **(2)**

A 2000 W electric kettle is connected to a 230 V supply.

(*iii*) Calculate the current flowing.

$\boldsymbol{I = \frac{P}{V} = \frac{2000}{230}}$ **(4)**

= 8.7 A **(2)**

(*iv*) Calculate the resistance of the kettle's element.

$\boldsymbol{R = \frac{V}{I} = \frac{230}{8.7}}$ **(4)**

$\boldsymbol{26.44\ \Omega}$ **(2)**

(*v*) Calculate the energy, in kilojoules, consumed by the kettle in 15 minutes.

$E = I^2Rt$ / $E = VIt$ **(2)**

30015 × 60 / 15 × 60 **(2)**

1800900 J **(2)**

6. Answer any two of the parts (a), (b), (c), (d). Each part carries 33 marks.

(*a*) Thulium–170 (Tm–170) is a radioisotope commonly used in portable X–ray equipment. It has a half-life of 128.6 days. It decays by beta emission.

(*i*) What is a radioisotope?
a radioactive isotope / unstable isotope that sheds energy release excess energy and particles in the form of radiation **(6)**

(*ii*) Write a nuclear equation to show the decay of **Tm**–170 by beta emission.
$^{170}_{69}\mathbf{Tm} \rightarrow {}^{170}_{70}\mathbf{Yb} + {}^{0}_{-1}\mathbf{e}$ **(3×3)**

A sample of Tm–170 initially contains 1.6×10^{20} radioactive atoms.

(*iii*) Calculate the number of atoms remaining after 643 days.
5 half-lives **(3)**
5×10^{18} **(3)**

(*iv*) Compare the penetrating ability of alpha and beta particles.
beta particles are more penetrating / alpha stopped by sheet of paper beta are not **(6)**

Cu–62 is a radioisotope used for medical imaging. It is injected into the bloodstream and a scan carried out to detect the gamma rays emitted.

(*v*) State the effect of gamma ray emission on the atomic number of Cu–62 atoms.
it has no effect **(3)**

(*vi*) State one precaution medical personnel should take when using radioisotopes.
lead apron / handle with tongs / (suitable) PPE **(3)**

(*b*) The image below shows a series of different types of radiation arranged in order of increasing wavelength.

(*i*) State the name of the series shown above.
electromagnetic spectrum **(3)**

(*ii*) State the speed of X–rays in a vacuum.
$2.99792458 \times 10^8 \text{m s}^{-1}$ / $3 \times 10^8 \text{ m s}^{-1}$ **(3)**

(*iii*) Name the radiation types labelled A and B.
A = visible Light **(3)**
B = microwaves **(3)**

(*iv*) Compare the frequencies of gamma rays and radio waves.
gamma rays have a greater frequency **(3)**

Under certain conditions <u>photons</u> cause electrons to be released from the surface of a metal.

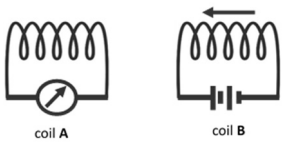
(*v*) Explain the underlined term.
quantum (packet) of light (electromagnetic) energy **(3)**

(*vi*) Identify this phenomenon.
photoelectric effect **(3)**

(*vii*) Calculate the frequency of a UV photon with a wavelength of 2.54×10^{-9} m.
$\mathbf{f = \frac{c}{\lambda} / f = \frac{2.997 \times 10^8}{2.54 \times 10^{-9}}}$ **(3)**
$f = 1.18 \times 10^{17}$Hz **(3)**

(*viii*) Calculate the energy of the UV photon in (*vii*).
$E = hf / E = 6.626 \times 10^{-34} \times 1.18 \times 10^{17}$ **(3)**
$E = 7.82 \times 10^{-17}$J **(3)**

(*c*) The diagram shows a coil A, at rest and attached to a galvanometer. Coil B attached to a d.c. supply, moves towards A. The galvanometer deflects.



(*i*) What is meant by electromagnetic induction?

emf induced **(3)**

by changing magnetic flux (field) **(3)**

(*ii*) State two factors which will determine the size of the deflection of the galvanometer.

speed of movement of B/ size of current flowing /voltage of d.c. supply/ no of turns in coil B **(2 × 3)**

(*iii*) What change in the deflection will occur if coil B is wrapped around a soft iron core? Justify your answer.

greater deflection **(3)**

greater magnetic field inside coil B **(3)**

(*iv*) What change in the deflection will occur if coil B is moved away from coil A? Justify your answer.

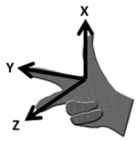
deflection in the opposite direction **(3)**

induced current is in the opposite direction **(3)**

(*v*) Under what circumstances might the galvanometer deflect if both coils are stationary?

if coil B is attached to an a.c. supply **(3)**

The Right-Hand Rule can be used to determine the direction of the current in a conductor as shown.



(*vi*) Which letter shows the direction of the current?

Z **(3)**

(*vii*) Which letter shows the direction of the magnetic field?

Y **(3)**

(*d*) An object starting from rest moves a distance of 90 m from A to B with constant acceleration of 20 m s^{-2}. For the next 7 seconds it then travels from B to C with constant velocity. It comes to rest at D with constant deceleration of 12 m s^{-2}.

(*i*) What quantity is defined as the rate of change of velocity?

acceleration **(3)**

(*ii*) Calculate the velocity at **B**.

$\mathbf{v^2 = u^2 + 2as}$ **(3)**

$\mathbf{v = 60\ m\ s^{-1}}$ **(3)**

(*iii*) Calculate the time taken to reach **B**.

$\mathbf{v = u + at\ /\ s = ut + \frac{1}{2}\ at^2}$ **(3)**

t = 3 s **(3)**

(*iv*) Calculate the time taken to travel from **C** to **D**.

v = u + at **(3)**

t = 5 s **(3)**

(*v*) Draw, on graph paper, a velocity-time graph to represent the motion of this object.

axes labelled **(3)**

v and t plotted correctly A to B **(3)**

v and t correctly B to C **(3)**

v and t correctly C to D **(3)**

7. **Any eleven parts**

(*a*) How many (*i*) electrons, (*ii*) neutrons, has the ion $^{56}_{26}Fe^{3+}$?

(*i*) 23

(*ii*) 30 **(4 + 2)**

(*b*) What is an atomic orbital?

high probability of finding an electron **(6)**

(*c*) Explain what is meant by the term isotope.

same atomic number

different number of neutrons **(4 + 2)**

(*d*) Write the chemical formula for manganese(IV) oxide.

MnO_2 **(6)**

(*e*) Calculate the percentage of carbon by mass in $(NH_4)_2CO_3$.

Mr = 96 **(2)**

$\frac{12}{96}$ **(2)**

× 100 = 12.5 % **(2)**

(*f*) State the colour observed in a flame test on a salt of (*i*) potassium (*ii*) sodium.

(i) lilac / purple

(ii) orange / yellow **(4 + 2)**

(*g*) State two differences between Mendeleev's periodic table and the modern periodic table of the elements.

(elements arranged) by atomic weight /reversed pairs of elements / left gaps (for undiscovered elements) / no noble gasses **[*any two*]** **(4 + 2)**

(*h*) Explain what is meant by the first ionisation energy of an element.

minimum energy (required to completely)

to remove (the most loosely bound) electron **(4 + 2)**

(*i*) Metals are good conductors of electricity. State two other physical properties of metals.

lustre / ductile / malleable / good conductors of heat **[*any two*]** **(4 + 2)**

(*j*) Identify two oxides that react with water to form acid rain.

carbon dioxide (CO_2) / sulphur dioxide (SO_2) / nitrogen dioxide (NO_2) **[*any two*]** **(4 + 2)**

(*k*) Name the process by which the application of an electric current to a substance results in a chemical change.

electrolysis **(6)**

(*l*) Identify the type of reaction involved in (*i*) the removal of oxygen (*ii*) the loss of electrons, from a compound.

(*i*) reduction

(*ii*) oxidation **(4 + 2)**

(*m*) The heat of solution of calcium chloride **$CaCl_2$** is –82.8 kJ mol^{-1}. Calculate the heat released when 55.5 g of calcium chloride is dissolved in water.

$\frac{55.5}{111} = 0.5$

0.5 × 82.8 = 41.4 kJ **(4 + 2)**

(*n*) Draw a diagram showing how hydrogen bonding arises between two water molecules.

hydrogen bond drawn between H and O atoms of two separate water molecules **(6)**

(*o*) Calculate the H^+ ion concentration in a monoprotic acid with a pH of 1.92.

$10^{-1.92}$ = $[H^+]$ / 1.92=- $\log_{10}[H^+]$/pH = -$\log_{10}[H^+]$

0.012 mol L = $[H^+]$ **(4 + 2)**

(*p*) Name a homologous series of organic compounds that contain (*i*) a hydroxyl group (*ii*) a carbonyl group.

(*i*) alcohol/ carboxylic acids

(*ii*) carboxylic acid / esters / ketones / aldehydes **(4 + 2)**

(*q*) Write a balanced chemical equation for the monochlorination of methane in the presence of uv light.

$$CH_4 + Cl_2 \xrightarrow{\text{(uv light)}} CH_3Cl + HCl$$ **(4 × 1 + 2)**

(*r*) Explain why benzene usually undergoes substitution rather than addition reactions.

stable / delocalised electrons **(6)**

8. (*a*) (*i*) What is meant by electronegativity?

relative attraction an atom has for **(3)**

a shared pair of electrons in a covalent bond. **(3)**

(*ii*) State and explain the trend in electronegativity values across the second period of the periodic table.

increases

effective nuclear charge increasing / atomic radius decreasing **(4 + 2)**

(*b*) The following covalent hydrides are formed by elements in the second period of the periodic table.

NH_3 **BeH_2** **H_2O** **CH_4**

(*i*) Using electronegativity values, arrange the molecules in the above list in order of increasing bond polarity.

ΔEN = 0.35 **ΔEN = 0.63** **ΔEN = 0.84** **ΔEN = 1.24** **(2)**

CH_4 **BeH_2** **NH_3** **H_2O** **(4)**

(*ii*) Describe how electronegativity values can be used to predict the type of bond that occurs between a pair of atoms.

(ΔEN) ≈ 0 non-polar covalent **(2)**

(ΔEN) > 0 - 1.7 polar covalent **(2)**

(ΔEN) > 1.7 ionic **(2)**

(*iii*) Identify one compound from the list above containing a non-polar covalent bond.

CH_4

(*iv*) Identify one compound from the list above containing a polar covalent bond.

BeH_2 / NH_3 / H_2O

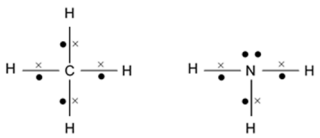
(*v*) Explain whether you would expect H_2O or H_2S to have the stronger bond.

H_2O

greater difference in electronegativity **(6 + 2 + 2 + 2)**

(*c*) (*i*) Draw a dot and cross diagram to show the arrangement of the valence electrons in CH_4 and NH_3.

(2 × 6)



(*ii*) Use electron pair repulsion theory to predict and explain the shapes of the **CH_4** and **NH_3** molecules.

tetrahedral

pyramidal

lone pair of electrons have a greater force of repulsion than bonded pairs. **(5 + 2 + 2)**

(*iii*) Which of these two compounds, CH_4 or NH_3, would you expect to be the more soluble in the non-polar solvent cyclohexane? Justify your answer.

CH_4

both non-polar compounds **(4 + 2)**

(*iv*) Explain why the molecule H_2O has a dipole moment while BeH_2 does not.

Be has no lone pair / BeH_2 is symmetrical / centre of positive and negative charge coincide **(3)**

9. (*a*) A white solid $MHCO_3$, where M represents a metallic element, is a weak base that dissolves in water. This solution undergoes neutralisation when titrated against a standardised solution of hydrochloric acid (HCl).

(*i*) Explain the underlined terms.

reaction between an acid and a base
to form a salt and water **(4 + 2)**

solution whose concentration has been determined accurately
by titration against a standard solution **(4 + 2)**

(*ii*) Suggest a primary standard that could be used to standardise the hydrochloric acid.

anhydrous sodium carbonate / Na_2CO_3 **(3)**

(*iii*) State two precautions that should be taken to avoid error when preparing the burette for a titration.

clamp vertically / ensure the part below the tap is full / remove funnel / rinse with deionised water / rinse with solution / no air bubbles / read at eye-level
[*any two*] **(4 + 2)**

(*iv*) State two precautions that should be taken while usin)g the conical flask to ensure an accurate end point.

swirl to mix contents // wash down walls with deionised water // stand on white tile
[*any two*] **(4 + 2)**

(*b*) (*i*) Name a suitable indicator for the titration. Justify your choice.

methyl orange / methyl red
strong acid – weak base titration **(4 + 2)**

(*ii*) State the colour change that occurs at the endpoint.

yellow / orange
pink / peach / red **(4 + 2)**

(*iii*) What was observed during the titration to indicate that a gas was produced?

fizzing / effervescence / frothing / bubbles **(3)**

(*c*) The $MHCO_3$ solution was prepared by dissolving 2.0 g of $MHCO_3$ in deionised water and making the solution up to 250 cm^3. On average 19.2 cm^3 of 0.104 M HCl solution was required to neutralise 25 cm^3 portions of the $MHCO_3$ solution according to the following balanced equation:

$$MHCO_3 + HCl \rightarrow MCl + H_2O + CO_2$$

(*i*) Calculate the concentration of the $MHCO_3$ solution in moles per litre.

$\frac{M_1V_1}{n_1} = \frac{M_2V_2}{n_2}$ / $\frac{0.104 \times 19.2}{1} = \frac{M_2 \times 25}{1}$ **(6)**

M_2 = 0.08 M **(2)**

//

$\frac{0.014}{1000}$ **×19.2=0.001997 moles** $\left(1.997 \times 10^{-3}\right)$ **(3)**

0.001997 $\frac{\text{moles}}{25cm^3}$ **$MHCO_3$** **(3)**

$\frac{0.001997}{25}$ **× 1000 = 0.0799** $\frac{\text{moles}}{\text{litre}}$ **(2)**

(*ii*) Calculate the number of moles of **$MHCO_3$** in the 250cm^3 of solution.

$= \frac{0.0799}{4}$ **= 0.01997 moles** **(2)**

(*iii*) Calculate the mass of 1 mole of **$MHCO_3$**.

$\frac{2}{0.01997}$ **(2)**

1 mole = 100.2 g **(2)**

(*iv*) Identify the element M.

$M + 61 = 100.2$

$M = 39.2$

M = potassium (K) **(6 + 2 + 2)**

[must show calculations for award of 9 marks]

10. (*a*) (*i*) What is meant by the term oxidising agent?

A substance that brings about oxidation by accepting electrons from another substance. **(3)**

(*ii*) Arrange the following list of metals in order of their increasing ability to act as oxidising agents.

Al Ag Cu Mg Zn Na

Na	**Mg**	**Al**	**Zn**	**Cu**	**Ag**

(6×1)

[award 3 marks if reversed] [award 3 marks if first and last correct]

(*iii*) Select a metal from the list in part (*ii*) which reacts easily with dilute hydrochloric acid.

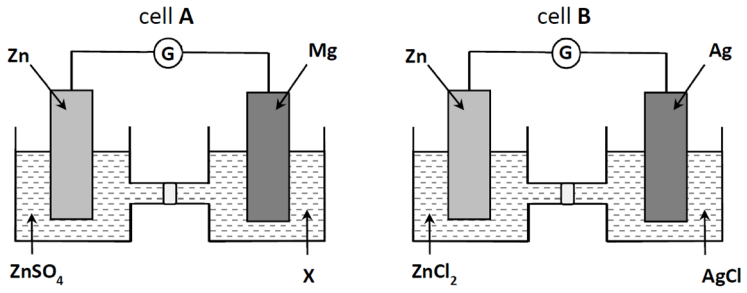
Na / Mg / Al / Zn **(3)**

(iv) Write a balanced chemical equation for the reaction with the chosen metal.

$2Na + 2HCl \rightarrow 2NaCl + H_2$ / $Mg + 2HCl \rightarrow MgCl_2 + H_2$ / $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$/ $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

(4 × 1 + 2)

(*b*) The image below shows two cells A and B both having a porous glass disc separating two solutions. The deflection of the galvanometer, G, indicates the flow of electrons in both cell A and cell B.



(*i*) State the direction of the flow of electrons in cell B above.

Justify your answer

State: Zn to Ag **(3)**

Justify: Zn is above Ag in the electrochemical series / Zn has a greater tendency to lose electrons **(6)**

(*ii*) In which cell does the galvanometer show the greatest deflection? Explain your answer.

Which: B **(3)**

Explain: Zn and Ag are further apart in the electrochemical series than Mg and Zn

(6)

(*iii*) Identify the solution X in cell A.

$MgSO_4$ / magnesium sulphate **(3)**

(*iv*) Which metal acts as the cathode in cell A?

Zinc / Zn **(3)**

(*c*) Magnesium (Mg) can be produced commercially by electrolysis of a molten electrolyte using inert electrodes.

(*i*) Explain the underlined term.

Electrodes do not take part in the reaction **(3)**

(*ii*) Identify a suitable salt that can be used as the molten electrolyte.

$MgCl_2$ / magnesium chloride **(3)**

(*iii*) Write a balanced chemical equation for the reaction occurring at the cathode.

$Mg^{2+} + 2e^- \rightarrow Mg$ **(3 × 1 + 3)**

A current of 5 A flows through the molten electrolyte for 20 minutes.

(*iv*) Calculate the charge transferred.

Q = It / Q = 5 x 20 x 60 = 6000C **(3)**

(*v*) Calculate the number of moles of electrons produced.

$\frac{6000}{96485.34}$ **= 0.0622 moles** **(3)**

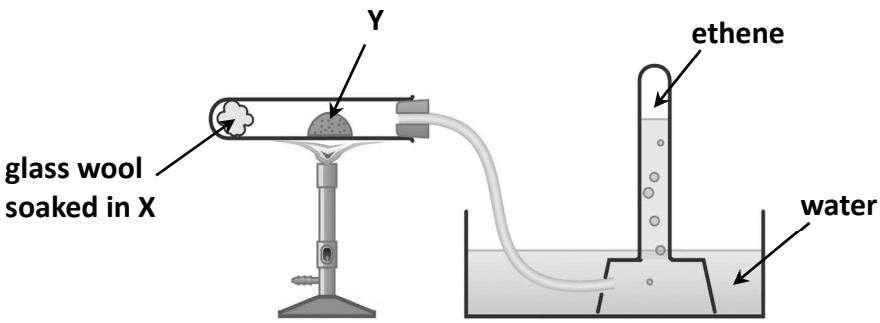
(*vi*) Calculate the number of moles of Mg produced.

$\frac{0.0622}{2}$ **= 0.0311 moles** **(3)**

(*vii*) Calculate the mass of Mg produced.

0.0311 × 24 = 0.7464 g **(3)**

11. (*a*) Ethene is used as a starting material for a large number of industrial compounds. Ethene can be prepared in a school laboratory using the apparatus shown.



(*i*) Identify X and Y.

X = ethanol / C_2H_5OH **(3)**

Y = aluminium oxide / Al_2O_3 **(3)**

(*ii*) What is the purpose of the glass wool?

keeps ethanol at the end of the test tube **(3)**

(*iii*) Explain why it is possible to collect ethene over water.

ethene is insoluble in water **(3)**

The ethene collected is passed through a solution of acidified $KMnO_4$.

(*iv*) State the colour change that occurs.

purple **(3)**

to colourless **(3)**

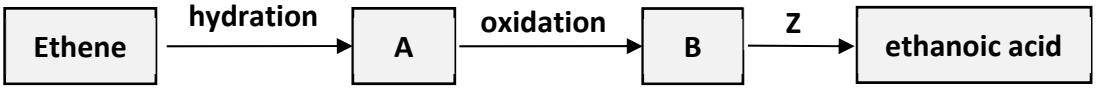
(*v*) Identify the property of ethene responsible for the colour change.

unsaturation **(3)**

(*vi*) Write a balanced chemical equation for the combustion of ethene.

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$ **(4 × 1 + 2)**

b) The reaction scheme shows how ethene can be converted to ethanoic acid.

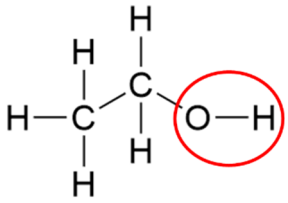


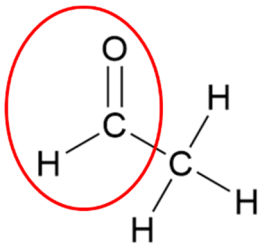
(*i*) Identify the compounds **A** and **B**.

A = ethanol / C_2H_5OH **(3)**

B = ethanal / CH_3CHO **(3)**

(*ii*) Draw the structure of a molecule of A and B, showing all the atoms and bonds.





(2 × 4)

(iii) Clearly label the functional group in each molecule from (*ii*).

correct functional group clearly labelled **(2 × 2)**

(*iv*) Identify the reaction type Z.

oxidation **(3)**

(*c*) (*i*) Identify the homologous series to which ethanoic acid belongs.

carboxylic acid **(3)**

(*ii*) Write a balanced chemical equation for the reaction of ethanoic acid with sodium hydroxide.

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$ **(4 × 1 + 2)**

(*iii*) Identify the ester produced when ethanoic acid reacts with methanol in the presence of sulfuric acid (**H_2SO_4**).

methylethanoate / CH_3COOCH_3 **(3)**

(*iv*) Explain why the reaction between ethanoic acid and methanol can be classified as a condensation reaction.

reaction between two smaller molecules **(3)**

to form a larger molecule and water **(3)**

12. Answer any three of parts (a), (b), (c), (d). Each part carries 22 marks

(a) (*i*) Write the *s*, *p*, *d* configuration of a neutral bromine atom.

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

$4s^2 3d^{10} 4p^5$ **(4 + 2)**

(*ii*) State and explain the trend in atomic radii down Group 17 in the periodic table.

increasing

additional shell

screening effect **(5 + 2 + 2)**

(*iii*) Arrange the following in order of decreasing atomic radii F^-, Br^-, F, Br.
Justify your answer.

Br^-, Br, F^-, F,

negative ion bigger than its atom

F smaller than Br **(3 + 2 + 2)**

(*b*) Hydrofluoric acid, HF, cannot be stored in glass bottles because compounds called silicates in the glass react with HF. Sodium silicate (Na_2SiO_3), for example, reacts as follows:

$$\mathbf{Na_2SiO_{3(s)} + 8HF_{(aq)} \rightarrow H_2SiF_{6(aq)} + 2NaF_{(aq)} + 3H_2O_{(l)}}$$

(*i*) How many moles of HF are required to react with 3.66 g of Na_2SiO_3?

M_r (Na_2SiO_3) = 122 **(3)**

$\frac{3.66}{122}$ = 0.03 moles **(3)**

0.03 × 8 = 0.24 moles **(3)**

(*ii*) How many oxygen atoms are present in 3.66 g of Na_2SiO_3?

$0.03 \times 3 \times 6 \times 10^{23} = 5.4 \times 10^{22}$ **(3)**

(*iii*) What mass of NaF is produced?

M_r (NaF) = 42 **(3)**

0.06 × 42 = 2.52 g **(3)**

(*iv*) How many molecules of water are formed?

0.03 × 3 = 0.09 **(2)**

$0.09 \times 6 \times 10^{23} = 5.4 \times 10^{22}$ **(2)**

(*c*) PCl_3 is one of the chlorides of phosphorous. PCl_3 reacts with water according to the equation: $PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3X$

(*i*) Identify compound X.

HCl / hydrochloric acid **(3)**

(*ii*) What term is used to describe a substance such as H_3PO_3 which acts as both an acid or a base?

amphoteric **(3)**

(*iii*) Write a balanced chemical equation for the reaction where **H_3PO_3** reacts as an acid with water.

$H_3PO_3 + H_2O \rightarrow H_2PO_3^- + H_3O^+$ **(4 × 1 + 2)**

(*iv*) Write a balanced chemical equation for the reaction where **H_3PO_3** reacts as a base with water.

$H_3PO_3 + H_2O \rightarrow H_4PO_3^+ + OH^-$ **(4 × 1 + 2)**

(*v*) Write the chemical formula for another chloride of phosphorous

PCl_5 **(4)**

(*d*) (*i*) Define heat of formation.

heat change when 1 mole of a compound

is formed from its elements (in their standard states) **(4 + 2)**

(*ii*) Write a balanced chemical equation to represent the formation of one mole of methane (CH_4).

$C_{(s)} + 2H_{2(g)} \rightarrow CH_{4(g)}$ **(3 × 1 + 1)**

(*iii*) Calculate the heat change for the reaction: $3C_{(s)} + 4H_{2(g)} \rightarrow C_3H_{8(g)}$ from the following data:

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -393.5$ kJ mol^{-1}

$H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$ $\Delta H = -285.8$ kJ mol^{-1}

$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$ $\Delta H = -2220.1$ kJ mol^{-1}

= – 1180.5 **(2 [*multiplicative factor*] + 1 [*sign*])**

= – 1143.2 **(2 [*multiplicative factor*] + 1 [*sign*])**

= + 2220.1 **(2 [*multiplicative factor*] + 1 [*sign*])**

ΔH = – 103.6 kJ **(3)**