Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2026

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.

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. Answer eleven of the following items (a), (b), (c), etc. All the items carry equal marks. Keep your answers short.

(*a*) Distinguish between a vector and a scalar quantity.

a scalar quantity has magnitude only /

a vector quantity has (magnitude and) direction **[6]**

(*b*) Two speed cameras, located 9 km apart, record a motorist's average speed as 108 km per hour. Calculate the time taken, in seconds, for the motorist to travel between the two cameras.

t = 9 ÷ 108 = 0.083 hours

0.083 × 3600 = 298.8 / 300 s **[4+2]**

(*c*) Define the SI unit of energy, the Joule.

(work done when a force of) 1 newton/ 1 N

moves a mass 1 m (in the direction of the force) **[4+2]**

(*d*) Cart A of mass 500 g is travelling horizontally with a speed of 4 m s^{-1}. It collides with cart B of mass 250 g travelling in the opposite direction with a speed of 6 m s^{-1}. Cart A comes to rest as a result of the collision. Calculate the new velocity of cart B.

(0.5)(4) + (0.250)(–6) = (0.5)(0)+0.250v / formula

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

(*e*) Draw a ray diagram to show the formation of an upright, magnified, virtual image in a concave mirror.

concave mirror

object inside focal point

apparent intersection of rays to form virtual image [any 2] **[4+2]**

(*f*) An object is placed 3 cm from a convex (converging) lens. A virtual image is formed 4 cm from the lens. Calculate the focal length of the lens.

$1/u + 1/v = 1/f$ **[2]**

substitution **[2]**

f = 12 (cm) ` **[2]**

(*g*) What is meant by dispersion of light?

splitting of light

into its different colours **[4+2]**

(*h*) Distinguish between longitudinal and transverse waves.

longitudinal :vibration parallel to the direction of motion /

transverse: vibration perpendicular to direction of motion **[4+2]**

[diagrams acceptable]

(*i*) Calculate the frequency of an electromagnetic wave of wavelength 1.5 mm travelling through a vacuum.

1.5×10^{-3} m **[2]**

c = fλ /f = $\frac{c}{\lambda}$ **[2]**

1.999×10^{11} (Hz)/ 2 x 10^{11} (Hz) **[2]**

(*j*) State the name given to the temperature at which water, ice and steam exist in equilibrium. What is the value of this temperature on the Kelvin scale?

triple point

273.16 K **[4+2]**

(*k*) Explain how two identical beakers of the same liquid could have the same temperature but contain different quantities of heat.

reference to mcΔθ /different mass / different volume / different amount (of water) **[6]**

(*l*) State two assumptions of the kinetic theory of gases.

particles colliding elastically // particles with no net loss or gain of energy // particles with no forces between them //

particles with collisions of negligible duration etc. [*any two*] [4+2]

(*m*) Copy and complete the diagram on the right to show the shape and direction of the magnetic field lines around the wire carrying current *I*.

correct shape

correct direction [4+2]

(*n*) The primary coil of a transformer in a phone charger has 1200 turns. It is connected to a 230 V mains supply. Calculate the number of turns required in the secondary coil to generate an output of 4.6 V.

$\frac{Vi}{Vo} = \frac{Np}{Ns}$ **[2]**

substitution [2]

Ns = 24 [2]

(*o*) State the principle on which the operation of the moving-coil galvanometer is based.

a current carrying conductor in a magnetic field / current in a coil experiences a force [4+2]

(*p*) Compare the ionising abilities of beta particles and gamma rays.

beta particles have a higher ionising ability / beta higher / gamma lower [6]

(*q*) Explain why nuclear fusion reactions require such high temperatures.

to provide (high kinetic) energy/high speeds

in order to overcome electrostatic/ repulsive forces [4+2]

(*r*) Identify particle X which is formed by the fusion of two helium–3 nuclei as shown by the equation: $^{3}_{2}\mathbf{He} + {}^{3}_{2}\mathbf{He} \rightarrow {}^{4}_{2}\mathbf{He} + \mathbf{2X}$

$^{1}_{1}$ // H **[4+2]**

2. (*a*) A student completed an experiment to calculate a value for the acceleration due to gravity, *g*.

(*i*) Draw a labelled diagram of the arrangement of the apparatus used in this experiment.

timer // timer [4]

ball and release mechanism // string [4]

pressure plate // correct arrangement of bob [4]

(*ii*) What measurements were taken to calculate *g*?

distance (s) // length (l) [4]

time (t) // period of oscillation (T) [4]

(*iii*) Describe how these measurements were taken.

measurement 1 correctly described [2]

measurement 2 correctly described [2]

(method must match setup described in (i))

(*iv*) How were these measurements used to calculate *g*?

s = $\frac{1}{2}gt^2$ /g = $\frac{2s}{t^2}$ // T = 2π$\sqrt{\frac{l}{g}}$ / g = $\frac{4\pi^2 l}{T^2}$ [3]

(*b*) A ball with a mass of 6.0 kg and a feather with a mass of 1.5×10^{-3} kg at the same height are dropped vertically from rest in a near perfect vacuum. 2.04 s later they both strike the ground.

(*i*) Explain why the ball and feather strike the ground at the same time.

acceleration due to gravity the same for both /no air resistance so fall at same speed [3]

(*ii*) Calculate the velocity of the objects at the moment they strike the ground.

v= u +at / substituted formula

= 20 ms^{-1} [4+2]

(*iii*) Calculate the initial height of the objects above the ground.

s = ut + $\frac{1}{2}at^2$/ $v^2 = u^2 + 2as$ [2]

s = 20.39 (m) [2]

(*iv*) Calculate the kinetic energy of the ball as it strikes the ground.

K.E. = $\frac{1}{2}mv^2$

$\frac{1}{2}(6)(19.99)^2$ = 1198.8 J [4+2]

(*v*) By what factor does the kinetic energy of the ball differ from the kinetic energy of the feather at the instant they strike the ground?

$\frac{6.0}{1.5\times10^{-3}}$ = 4000 [2]

(c) (i) State Newton's universal law of gravitation.

force is proportional to product of masses / F $\propto m_1 m_2$

force is inversely proportional to distance squared / F$\propto \frac{1}{d^2}$

OR

$$\boldsymbol{F = G\frac{m_1 m_2}{d^2}}$$ **[4+2]**

(*ii*) Using this law, derive the relationship between *g*, the acceleration due to the Earth's gravity and *G*, the gravitational constant.

$$\boldsymbol{G\frac{m_1 m_2}{d^2} = mg}$$ **[2]**

$$\boldsymbol{\frac{GM}{d^2} = g}$$ **[2]**

The Moon is Earth's only natural satellite.

(*iii*) Calculate the attractive force between the Earth and the Moon.

formula

$$\boldsymbol{(6.674 \times 10^{-11})(5.9 \times 10^{24})(7.3 \times 10^{22}) \div (3.8 \times 10^{8})^2}$$

$$\boldsymbol{= 1.99 \times 10^{20}\ N / 2 \times 10^{20}\ N}$$ **[6+2]**

3. (*a*) (*i*) What is meant by refraction of light?

(refraction is) the bending of light // when it enters a different medium **[4+2]**

(*ii*) What is meant by the term critical angle?

angle of incidence (in denser medium)

such that // gives an angle of refraction is 90° **[4+2]**

(*b*) In an experiment to verify Snell's law, the angle of incidence *i* and the angle of refraction *r* for a ray of light as it passes from air into glass was measured and the following data collected.

i (degrees)	30	40	50	60	70	80
r (degrees)	20	26	33	38	42	44

(*i*) Draw a labelled diagram of the arrangement of the apparatus used in this experiment.

transparent block //

ray box / laser / pins //

detail e.g. paper, ruler, protractor // [any two] **[6+3]**

(*ii*) Draw a suitable graph to verify Snell's law.

values for sin *i* and sin *r* **[3]**

Sin i	0.5	0.64	0.77	0.87	0.94	0.98
Sin r	0.34	0.44	0.54	0.62	0.67	0.69

labelled axes **[3]**

6 points plotted **[6]**

(straight) line with good fit **[3]**

(*iii*) Explain how your graph verifies Snell's law.

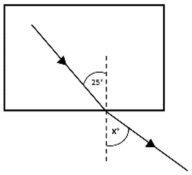
sin i ∝ sin r / straight line through origin **[3]**

(*iv*) Use your graph to determine the refractive index of the material.

slope = n / slope formula

n = 1.4 [maximum of 4 marks if graph not used] **[4+2]**

(*c*) A ray of light is incident on the internal boundary of a rectangular acrylic block in air, as shown. The refractive index of acrylic is 1.49.



(*i*) State the change that occurs, if any, in the speed of the ray of light as it travels from the acrylic into air.

increases **[3]**

(*ii*) Calculate the angle of refraction **X**.

1.49 = $\frac{sinX}{sin25}$ **/ formula**

X = 39℃ **[4+2]**

(*iii*) Determine the critical angle of acrylic.

1.49 = 1 / sin C / formula

C = 42.16° **[4+2]**

(*iv*) Sketch a diagram to predict the path of the ray of light when the angle of incidence exceeds the critical angle of acrylic.

ray showing total internal reflection **[6]**

4. (*a*) Brownian motion, which was first observed in 1877, provided evidence for the kinetic theory of gases.

(*i*) What is meant by the term Brownian motion?
rapid zig - zag motion of particles in a fluid

(*ii*) Describe how Brownian motion can be demonstrated in a school laboratory.
arrangement of smoke cell / pollen in water etc.
view with microscope

(*iii*) State two ways Brownian motion provides evidence for the kinetic theory of gases.
random motion // collision between particles // temperature dependence

(*iv*) State one contribution to atomic theory resulting from the observation above.
first direct evidence for the existence of atoms

[6+4+2+2+2+2]

(*b*) The growing understanding of the properties of matter led to the development of a wide range of measuring instruments, including the thermometer.

(*i*) What are the two reference temperatures used to establish the Celsius scale?
0 (°C)
100 (°C)

(*ii*) Describe how each of these reference temperatures can be measured in the laboratory.
place (unmarked) thermometer in crushed melting ice
place (unmarked) thermometer in boiling water

[6+2+2+2]

A constant volume gas thermometer, as shown, can be used as a standard thermometer.

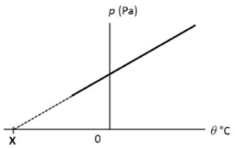
(*iii*) State two features of a gas thermometer which make it suitable for use as a standard thermometer.
accurate//independent of the gas used //wide range // sensitive//low heat capacity
[any two]

(*iv*) Explain why the tube labelled **C** should be kept as short and narrow as possible.
to minimise the volume of gas outside the bulb

(*v*) Identify a gas suitable for use in the gas thermometer at very low temperatures. Justify your answer.
helium / He
behaves as an ideal gas (at low temperatures)

[6+6+2+2+2]

(*c*) The graph shows how the pressure *p* of a gas varies with temperature θ, on the Celsius scale, at constant volume *V*.



(*i*) State the precise fixed value of the temperature **X**.
-273.15

(*ii*) State the average kinetic energy of the gas particles at temperature **X**?
0 (J)

(*iii*) Show the relationship between the equation of state for the ideal gas and the slope of the graph shown.
$\frac{p}{T} = \frac{nR}{V}$

(*iv*) Copy the graph shown into your answerbook. On your graph sketch a line showing how the slope changes when the volume is doubled.
straight line through X / less steep slope

[6+6+2+2+2]

5. (*a*) (*i*) What is meant by electrical resistance?

opposition to the flow of electric charge/ $\frac{V}{I}$ = R at constant temperature **[3]**

(*ii*) Define the unit of electrical resistance, the ohm.

the resistance of a conductor is 1 ohm **[2]**

current of 1 ampere flows through it **[2]**

when the potential difference (between its ends) is 1 volt **[2]**

(*iii*) Explain why the resistance of a metallic conductor increases with temperature.

increased atomic vibrations **[3]**

increasing collisions **[3]**

(*iv*) State two other factors that affect the resistance of a metallic conductor.

cross sectional area // length //resistivity of material (any two) **[2×3]**

(*b*) A constant current was passed through a fixed mass of water, at room temperature, for varying lengths of time *t*. The temperature of the water θ was recorded after each time interval as shown in the table below.

t (s)	0	10	20	40	60	80	100
θ (°C)	15.9	17.2	18.4	20.5	23.2	25.6	28.0

(*i*) Draw a graph, on graph paper, to show the relationship between *t* and ϑ.

labelled axes **[3]**

points plotted **[6]**

straight line with good fit **[3]**

(*ii*) State the relationship between *t* and θ.

linear **[2]**

(*iii*) Use your graph to estimate the temperature of the room before the current begins to flow. Justify your answer.

16 ° **[2]**

conductor will be at room temperature **[3]**

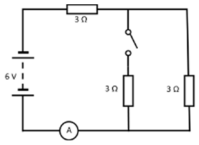
(*iv*) Use your graph to estimate the temperature of the water after 67 s.

≈24 ° **[2]**

(*v*) Use your graph to determine the time taken to increase the temperature of the water by 11 °C.

≈90 s **[3]**

(*c*) Use the circuit diagram below to answer the following questions.



(*i*) Calculate the reading on the ammeter when the switch is *open.*

R_T = 3 + 3 = 6 Ω **[3]**

I = 6 V / 6 Ω = 1 A **[3]**

(*ii*) Calculate the reading on the ammeter when the switch is *closed.*

$\frac{1}{R_T} = \frac{1}{3} + \frac{1}{3}$ **[3]**

R_T = 3 Ω + 1.5 Ω = 4.5 Ω **[3]**

I = 1.3 A **[3]**

(*iii*) Sketch a circuit diagram to show how the three resistors shown could be arranged to give a reading of 6 A on the ammeter.

3 resistors in parallel **[6]**

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

(*a*) Electric fields exist around charged objects.

(*i*) What is an electric field?

region/space (around a charge in which another) //
charged particle will experience a force **[4+2]**

(*ii*) Name an instrument which can be used to detect the presence of an electrical field.

electroscope etc. **[3]**

(*iii*) What is the unit of electric charge?

coulomb / C **[3]**

(*iv*) Draw a labelled diagram to show how an electric field pattern can be demonstrated in the laboratory.

dish of (castor) oil //
high voltage source //
two electrodes/plates //
semolina forms electric field pattern [any two] **[4+4]**

(*v*) Describe how an insulated spherical conductor can be charged negatively by induction.

bring positively charged rod close to conductor //
conductor earthed //
earth removed //
then remove rod [any two] **[4+4]**

(*vi*) Draw the electric field pattern around the negatively charged sphere.

radial field lines directed towards sphere **[3]**

The charged sphere is then earthed.

(*vii*) Draw a diagram to show the type and distribution of charge on the sphere after earthing.

diagram showing equal number of positive and negative charges **[2]**

(*b*) (*i*) What is meant by the half-life of a radioactive isotope?

the time taken / $T_{\frac{1}{2}}$ // for half of the nuclei to decay / $\frac{ln\,2}{\lambda}$ / $\frac{0.693}{\lambda}$ **[4+2]**

The table shows the radioactive decay of a sample of Thallium–201 measured over a 240-hour period.

time (hours)	0	40	80	120	160	200	240
mass (mg)	2	1.37	0.94	0.64	0.44	0.25	0.21

(*ii*) Draw a graph, on graph paper, to represent this data.

labelled axes **[3]**
points plotted **[6]**
curved line with good fit **[3]**

(*iii*) Use your graph to estimate the half-life of Tl–201.

value from graph ≈ 72 hours **[3]**

The nuclear equation below represents the beta decay of another isotope of thallium, Tl–208. $^{208}_{81}\text{Tl} \rightarrow {}^{X}_{Y}\text{Z} + {}^{0}_{-1}\text{e}$

(*iv*) Identify the number **X**.

X = 208

(*v*) Identify the number **Y**.

Y = 82

(*vi*) Identify the element represented by **Z**.

Z = Pb

(*vii*) Identify the element whose alpha decay results in the formation of the element gold, Au–197.

Thallium / Tl **[4+4+2+2]**

(*c*) (*i*) What is meant by capacitance?

$C = \frac{Q}{V}$ / measure of ability to store charge **[5]**

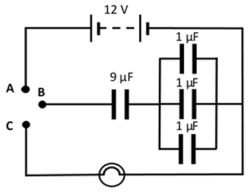
(*ii*) State three factors on which the capacitance of a parallel plate capacitor depends.

common area

distance between plates

permittivity of dielectric / material **[6+4+2]**

A 12 V battery is connected to four capacitors arranged as shown.



(*iii*) Calculate the effective capacitance of the circuit.

1 + 1 + 1 = 3 μF **[2]**

$\frac{1}{C_T} = \frac{1}{3} + \frac{1}{9}$ **[2]**

C_T = 2.25 μF / 2.25 × 10^{-6} F **[2]**

(*iv*) Calculate the charge stored in the circuit when B is connected to A.

Q = (2.25 × 10^{-6})(12) **[2]**

= 27 × 10^{-6} C / 27 μC **[2]**

(*v*) What would be observed if B is then connected to C? Justify your answer.

the bulb flashes //

capacitors discharge //

sending a current through the bulb **[any two]** **[4+2]**

(*d*) (*i*) Explain what is meant by a monochromatic light source.

(emits light consisting of) one wavelength/ frequency

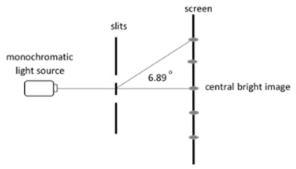
(*ii*) Explain what is meant by the term interference.

when two waves meet and add

(*iii*) Distinguish between constructive and destructive interference.

Constructive: the amplitude of the resultant wave is greater than that of the individual waves **[5+5+2]**

Monochromatic light falls on a pair of Young's slits 0.015 mm apart producing an interference pattern on a screen as shown in the diagram below.



(*iv*) Calculate the wavelength of the light.

(0.015 × 10^{-3}) Sin 6.89 = 2λ / formula

$\lambda = \frac{1.799x10^{-6}}{2}$

λ = 8.9972 × 10^{-7} m **[5+2+2]**

(*v*) Calculate the energy of a photon of this wavelength.

E = h$\frac{c}{\lambda}$ / E = hf /c = λf

E = 6.626 × 10^{-34} × $\frac{2.9979\times10^{8}}{8.9972\times10^{-7}}$ /E = 6.626x10^{-34}x 3.332x10^{14}/ 2.9979x10^{8}= 8.9972x10^{-7}f

E = 2.21× 10^{-19} J **[5+2+2]**

(*vi*) What other phenomenon occurs as the light passes through the slits?

diffraction **[3]**

7. Answer eleven of the following items (a), (b), (c), etc. All the items carry equal marks. Keep your answers short.

(*a*) How many (*i*) protons and (*ii*) electrons are there in a $^{40}_{20}Ca^{2+}$ ion?

(i) 20

(ii) 18 **[4+2]**

(*b*) State two reasons why the electronegativity value of potassium is less than that of sodium.

increase in shielding / screening

increase in atomic radius / K has more energy levels **[4+2]**

(*c*) Calculate a value for the relative atomic mass of a sample of boron (B) composed of 19.9% boron–10 and 80.1% boron–11.

(19.9 × 10) + (80.1 × 11) = 1080.1

1080.1÷ 100 = 10.801 **[4+2]**

(*d*) Write the chemical formulae for:(*i*)copper(I) oxide and (*ii*)iron(III) oxide.

(i) Cu_2O

(ii) Fe_2O_3 **[4+2]**

(*e*) Graphite is an allotrope of carbon. Explain why graphite is

(*i*) a good electrical conductor,

(*ii*) a good lubricant.

(i) (presence of) free electrons

(ii) layered structure (held by weak intermolecular forces) **[4+2]**

(*f*) State two possible shapes for covalent molecules of general formula AB_3.

(trigonal) planar

(trigonal) pyramidal **[4+2]**

(*g*) Calculate the percentage by mass of chromium (Cr) in $K_2Cr_2O_7$.

Mr = 294.2 **[2]**

104 ÷ 294.2 = 0.3535 **[2]**

0.3535 × 100 = 35.35 % **[2]**

(*h*) State two properties of transition metals.

form coloured compounds // variable valency // good catalysts **[any two]** **[4+2]**

(*i*) Identify from the following list (*i*) a basic oxide and (*ii*) a covalent hydride.

Al_2O_3 MgH_2 PH_3 Na_2O

(i) Na_2O

(ii) PH_3 **[4+2]**

(*j*) Identify, in methane (CH_4), the type of:

(*i*) *intramolecular* bonding present,

(*ii*) *intermolecular* forces present.

(i) covalent

(ii) Van der Waals **[4+2]**

(*k*) Identify two metals from the list shown that will not liberate hydrogen from dilute hydrochloric acid:

Al Ag Zn Mg Cu

Cu

Ag **[4+2]**

(*l*) What is meant by the heat of reaction?

heat change / amount of energy released or absorbed // during a chemical reaction **[4+2]**

(*m*) Copy, complete and balance the following chemical equation:

$2HCl + Mg(OH)_2 \rightarrow$ **$MgCl_2$ + $2H_2O$** **[2×2 + 2]**

(*n*) Under what circumstances can ionic compounds conduct electricity?

molten / liquid

dissolved in water **[4+2]**

(*o*) For a crystal of potassium chloride (KCl) identify (*i*) the types of particles that occupy the lattice points, (*ii*) the forces that bind these particles together.

ions

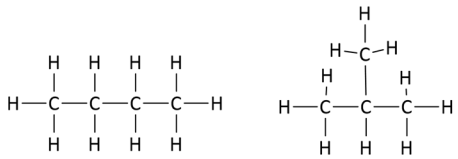
ionic bonding **[4+2]**

(*p*) Identify the reagent required and the necessary condition for the conversion of CH_4 to CH_3Cl.

Cl_2

uv light **[4+2]**

(*q*) Draw the structures of the two compounds that have the molecular formula **C_4H_{10},** showing all atoms and all bonds.

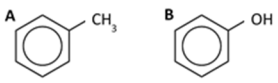


[4+2]

(*r*) Name the aromatic compounds **A** and **B** shown.

A = methyl benzene / toluene

B = phenol /benzenol /hydroxybenzene **[4+2]**



8. (*a*) Neils Bohr used the emission spectrum of hydrogen to describe the arrangement of the electrons in energy levels.

(*i*) What is meant by the term energy level?
fixed energy of an electron **[4]**

(*ii*) Describe the arrangement of electrons in the energy levels n = 1 to n = 3 according to Bohr's theory.
correct number of electrons in each level / 2, 8, 18 / $1s^2$, $2s^2 2p^6$, $3s^2 3p^6 3d^{10}$ **[4]**

(*iii*) Name the series of visible lines in the hydrogen emission spectrum.
Balmer series **[4]**

(*iv*) Explain the origin of the series of visible lines in the emission spectrum of hydrogen.
electron absorbs energy / electron in ground state //
move to higher energy level / excited state //
unstable //
releases (energy as) photon (of definite frequency) **[any 3]** **[3 × 3]**

(*v*) Describe the relationship between the frequency of a line in the hydrogen emission spectrum and two of the main energy levels in a hydrogen atom.
$E_2 - E_1 = hf$ /
energy emitted (*hf*) corresponds to difference between the two energy levels ($E_2 - E_1$) **[6]**

(*b*) The emission spectrum of various metals such as sodium and potassium can be viewed by allowing the light from a flame test on the metal salt to pass through a spectroscope.

(*i*) Describe how you would conduct a flame test on metal salts of sodium and potassium.
damp splint in salt / dip platinum wire //
hold in(blue) Bunsen flame //
use new splint / clean platinum wire **[any 2 correct]**

(*ii*) State the colour observed in a flame test on a salt of sodium.
yellow / orange

(*iii*) State the colour observed in a flame test on a salt of potassium.
lilac / purple

(*iv*) Explain why the emission spectra of sodium and potassium are different.
different numbers of electrons / electron configurations / K has more electrons
[6+6+2+2+2]

(*c*) (*i*) Write the full s, p, d electron configuration for an atom of vanadium (**V**) in its ground state, including the number of electrons in each atomic sublevel.
$1s^2\ 2s^2\ 2p^6$
$3s^2\ 3p^6\ 4s^2\ 3d^3$ **[6+3]**

(*ii*) State the total number of orbitals occupied by the electrons in an atom of vanadium.
13 **[3]**

(*iii*) Describe the arrangement of electrons in a full p sublevel.
$p_x^2\ p_y^2\ p_z^2$ / suitable diagram **[3]**

(*iv*) How do the atomic orbitals in a p sublevel differ from each other?
orientation / x, y, z **[3]**

(*v*) One of the electrons in a vanadium atom is described by the set of quantum numbers {3, 1, –1, $+\frac{1}{2}$}. Specify the orbital occupied by this electron.
3p **[3]**

9. Propanoic acid (C_2H_5COOH) is a weak acid found in many everyday products, primarily as a preservative to prevent mould. A student carried out an investigation in a school laboratory to determine the concentration of propanoic acid in a solution of preservative by titration against a 0.2 M solution of sodium hydroxide (NaOH).

(*a*) (*i*) Describe how a 200 cm^3 sample of C_2H_5COOH solution, in a beaker, could be diluted to exactly 1000 cm^3.

(empty through) funnel into volumetric flask //
(include) rinsings //
fill with deionised water // until bottom of meniscus on mark //
reading at eye level [*any two*]

(*ii*) Name a piece of apparatus that could be used to accurately measure and transfer 25.0 cm^3 portions of the diluted **C_2H_5COOH** solution into a conical flask.

pipette / burette

(*iii*) Describe how this piece of apparatus was rinsed before use.

with deionised water //
with solution **[9+6+2+2+2]**

(*b*) The table below shows three indicators A, B and C with their pH range .

Indicator	pH range
A	3.8 – 5.4
B	6.0 – 7.6
C	8.0 – 9.8

(*i*) Which indicator from the table would be suitable for the above titration? Justify your choice.

C //
colour change coincides with the pH of the mixture at the endpoint of the titration / weak acid-strong base titration

(*ii*) Name a suitable indicator for this titration.

eg. phenolphthalein

(*iii*) State the colour change observed at the end point for the indicator in (*ii*).

e.g. colourless //
to pink

[7+2+2+2+2]

(*c*) 25.0 cm^3 of the diluted **C_2H_5COOH** solution was titrated against the 0.2 M **NaOH** solution. The titration reaction is described by the following balanced chemical equation:

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

One approximate and two accurate titrations were carried out. The results are shown in the table below.

Approximate titration	First accurate titration	Second accurate titration
16.9 cm^3	16.7 cm^3	16.6 cm^3

(*i*) Calculate the average volume (titre) of **NaOH** needed to neutralise the **C_2H_5COOH**.

16.7 + 16.6

÷ 2 = 16.65 **[4+2]**

(*ii*) Calculate the number of moles of **NaOH** in the average titre.

$\frac{0.20 \times 16.65}{1000}$

= 0.00333 (moles) / 3.3×10^{-3} / 3.0×10^{-3} / 0.003 **[3]**

(*iii*) Calculate the concentration of the *dilute* **C_2H_5COOH** solution in moles per litre.

0.00333 × 16.65 **//** $\frac{M_a \times 25}{1}$

÷ 1000 **//** $\frac{0.2 \times 16.65}{1}$

0.1332 (M) / 0.13 **[5+2+2]**

[*award 3 marks if formula given with no other calculations*]

(*iv*) Calculate the concentration of the *dilute* **C_2H_5COOH** solution in grams per litre.

M_r = 74.078 (74)

0.1332 × 74.078 = 9.86 (g) / 9.8 (g) **[4+2]**

(*v*) Calculate the concentration of the *original* **C_2H_5COOH** solution in grams per litre.

$\frac{1000}{200}$ **= 5 (dilution factor)**

9.86 × 5 = 49.3 (g) / 49 **[4+2]**

10. (*a*) (*i*) Explain what is meant by reduction in terms of electron transfer.

gain of electrons **[3]**

(*ii*) Identify the substance *reduced* in the following reaction. $CuO + H_2 \rightarrow Cu + H_2O$

CuO **[3]**

(*iii*) Identify the substance *oxidised* in the following reaction. $Zn + I_2 \rightarrow ZnI_2$

Zn **[3]**

(*iv*) Why is reduction always accompanied by oxidation?

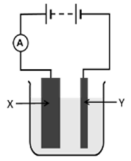
if electrons are gained by one species another species must lose electrons **[3]**

(*v*) Explain how Cu_2O acts as both an oxidising reagent and a reducing agent in the following reaction: $Cu_2O + 2H^+ \rightarrow Cu + Cu^{2+} + H_2O$

$Cu_2O \rightarrow$ Cu (reduced) **[3]**

$Cu_2O \rightarrow Cu^{2+}$ (oxidised) **[3]**

(*b*) The arrangement on the right can be used to purify 'blister' copper by electrolysis. This is a type of partially purified copper characterised by its blistered or bubbly surface due to the release of **SO_2** gas.



(*i*) State Faraday's first law of electrolysis.

mass or volume or amount of a substance liberated at an electrode **[3]**

is proportional to the quantity of charge that passes through an electrolyte **[3]**

(*ii*) What energy conversion occurs during electrolysis?

electrical **[3]**

to chemical **[3]**

(*iii*) Identify the two ions formed when copper(II) sulfate dissociates in solution.

Cu^{2+} **[3]**

SO_4^{2-} **[3]**

(*iv*) Which electrode X or Y is acting as the cathode? Justify your answer.

Y **[3]**

Cu^{2+} ions gain electrons at Y/ connected to negative terminal **[3]**

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

$Cu^{2+} + 2e^- \rightarrow Cu$ **[3×1+3]**

'Blister copper' can contain impurities such as silver (Ag) and gold (Au).

(*vi*) What happens to these impurities during electrolysis.

they do not react / fall to bottom of container **[3]**

It was observed during electrolysis that the blue colour of the copper(II) sulfate solution remained.

(*vii*) Explain this observation.

Cu^{2+} ions reduced at Y **[3]**

replaced by Cu atoms being oxidised at X **[3]**

(*c*) 3.6×10^4 C of charge flows through the above electrolytic cell in one hour.

(*i*) Calculate the current passing through the ammeter.

$3.6 \times 10^4 \div 3600 = 10$ A **[3]**

(*ii*) Calculate the number of moles of electrons flowing in the circuit.

no. of Faradays = $(3.6 \times 10^4) \div 96485.3$ **[3]**

= 0.3731 (moles of electrons) **[3]**

11. (*a*) (*i*) What is meant by the term homologous series?

A	C_2H_2
B	C_2H_5OH
C	HCOOH
D	C_6H_6

a group of organic compounds with **[3]**

same chemical and physical properties / functional group / differ by $-CH_2$ [any two] **[2x2]**

(*ii*) Name the homologous series to which compounds **A** to **D** belong.

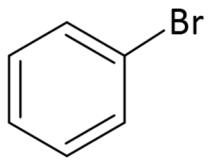
A = alkyne **[2]**

B = alcohol **[2]**

C = carboxylic acid **[2]**

D = aromatics **[2]**

(*b*) (*i*) Draw the structure of the main organic product of the reaction between compound **D** (C_6H_6) and Br_2.



[3]

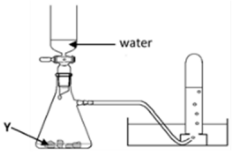
(*ii*) Classify this reaction as addition or substitution.

substitution **[3]**

(*iii*) Identify the catalyst involved in this reaction.

$Fe/FeBr_3$ **[3]**

(*c*) **C_2H_2** is a gaseous unsaturated hydrocarbon that can be prepared in a school laboratory using the apparatus shown.



(*i*) Identify solid **Y**.

calcium carbide / CaC_2 **[3]**

(*ii*) Write a balanced chemical equation for the preparation of **C_2H_2**.

$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$ **[4 × 1 + 2]**

(*iii*) What is meant by the term unsaturated hydrocarbon?

at least one carbon to carbon double or triple bond **[3]**

(*iv*) Describe how acidified potassium permanganate can be used to show **C_2H_2** is unsaturated.

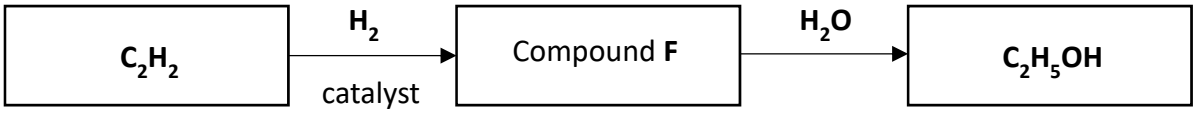
bubble C_2H_2 through potassium permanganate

purple solution decolourises **[6+3]**

(*v*) Draw the structure of the product of the addition of bromine to **C_2H_2** showing all atoms and bonds.

correct structure **[3]**

(*d*) Compound A can be converted to compound B via the following scheme.



(*i*) Identify a suitable catalyst for the synthesis of compound F from C_2H_2.
nickel / palladium / platinum **[3]**

(*ii*) Identify compound F.
ethene **[3]**

(*iii*) Classify the type of reaction occurring in the synthesis of C_2H_5OH from compound F.
addition / hydration **[3]**

Compounds B and C react together in the presence of sulfuric acid to form the ester G.

(*iv*) State the IUPAC name of ester G.
ethylmethanoate **[3]**

(*v*) Draw the structure of ester G, showing all atoms and all bonds.
correct structure

[6]

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

(*a*) (*i*) What is meant by the first ionisation energy of an element?

minimum energy required to (completely) remove //

the most loosely bound electron

The table shows the first eight ionisation energies of an atom of sulfur (**S**).

ionisation number	1	2	3	4	5	6	7	8
ionisation energy (kJ mol^{-1})	1000	2260	3390	4540	6990	8490	27100	31700

(*ii*) Explain how the 6th and 7th ionisation energy values of sulfur provide evidence supporting the existence of energy levels.

7th ionisation energy is (significantly) greater than the 6th

(*iii*) Write an equation to represent the second ionisation of sulfur.

$\mathbf{S^{+}_{(g)} \rightarrow S^{2+}_{(g)} + e^{-}}$

(*iv*) Explain why the second ionisation energy of an element is always greater than the first.

positive ion formed /

increase in effective nuclear charge /smaller atomic radius

[8+8+2+2+2]

(*b*) The following reaction shows the production of zinc nitrate $Zn(NO_3)_2$ which is used as a catalyst in many chemical reactions.

$$3Zn + 8HNO_3 \rightarrow 3Zn(NO_3)_2 + 2NO + 4H_2O$$

If 13 kg of zinc Zn granules are used in the reaction

(i) Calculate the number of moles of Zn used.

13kg = 13000g **[2]**

$\frac{13000}{65.41}$ **= 198.7 (moles)** **[2]**

(*ii*) Calculate the number of moles of nitric acid HNO_3 required.

$\frac{198.7}{3} \times 8$ **= 529.9 (moles)** **[3]**

(*iii*) Calculate the volume of nitrogen monoxide NO produced at s.t.p.

$\frac{198.7}{3} \times 2$ **= 132.5 (moles)** **[3]**

132.5 × 22.4 = 2968 (L) **[3]**

(*iv*) What mass of $Zn(NO_3)_2$ is produced?

Mr = 189.48 **[3]**

moles of $Zn(NO_3)_2$ = 198.7 **[3]**

198.7 × 189.48 = 37649.2 (g) **[3]**

(*c*) (*i*) What is meant by the term strong acid according to Brønsted-Lowry theory?

good proton donor

(*ii*) Copy and complete the following equation, assuming that H_2SO_4 acts as an acid.

$HSO_4^- + H_2NO_3^+$

(*iii*) Identify a conjugate pair in your equation.

H_2SO_4 and HSO_4^- / HNO_2 and $H_2NO_3^+$

(*iv*) State the relationship between pH and hydrogen ion concentration.

pH = $-log_{10}[H_3O^+]$ / higher $[H^+]$ lower pH

(*v*) Calculate the concentration of a solution of nitric acid HNO_3 with a pH of 1.2.

$[H_3O^+] = 10^{-pH}$ //

$[H_3O^+]$ = 0.063 mol L^{-1} **[8+6+2+2+2+2]**

(*d*) (*i*) What is meant by heat of combustion?

heat released //

when one mole of a substance is burnt in excess oxygen /completely **[2+2]**

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

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

$8H_{2(g)} + 7C_{(s)} \rightarrow C_7H_{16(l)}$ $\Delta H = -223.9$ kJ mol^{-1}

(*ii*) Use the data above to calculate the heat of combustion of heptane (C_7H_{16}) according to the following balanced chemical equation: $C_7H_{16(l)} + 11O_{2(g)} \rightarrow 7CO_{2(g)} + 8H_2O_{(l)}$

7(–393.5) **[= –2754.5]** **(2 *[multiplicative factor]* + 1 *[sign]*)**

+8(–285.8) **[= –2286.4]** **(2 *[multiplicative factor]* + 1 *[sign]*)**

–(–223.9) **[= +223.9]** **(2 *[multiplicative factor]* + 1 *[sign]*)**

= – 4817 kJ mol^{-1} **[3]**

(iii) Is this an exothermic or an endothermic reaction? Justify your answer.

exothermic

heat released / ΔH negative / reference to combustion **[4+2]**