Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2011

Marking Scheme

Physics and Chemistry

Higher Level

General Guidelines

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

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

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

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

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

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

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

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

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

Question 1
Any eleven parts **11×6**

(*a*) What energy conversion takes place as a child rises up through the air from the surface of a trampoline as shown in Figure 1? **2×3**
kinetic (energy to) …3
potential (energy) …3
[reversed …6]

(*b*) What is the relationship between *G*, the gravitational constant and *g*, the acceleration due to gravity? **6**
$g = \frac{Gm}{r^2}$ / $g = \frac{Gm}{d^2}$ …6

(*c*) Define the unit of power, i.e. *the watt.* **2×3**
one joule (used) / J / /one volt applied …3
every second / per s / / one amp flowing …3
[correct definition of power …3] [W = VI …3]

(*d*) Give one use for a convex mirror. **6**
wide field of view (mirror), car, rear view or wing (mirror), security (mirror), shop or bus (mirror), (obstructed) exit or dangerous bend (mirror) any one…6
[correct use for concave mirror, e.g torch (reflector) …3] [use of convex lens, e.g. glasses …3]

(*e*) Give two properties of the final image formed in a compound microscope. **5, 1**
magnified, inverted (in vertical plane), laterally inverted, at infinity or in normal adjustment.
Allow real.
first correct…5
second correct…1

(*f*) Why is sound classified as a longitudinal wave? **2×3 or 6**
medium or air (molecules) move(s) parallel / method of generation involves movement parallel …3
to direction (of propagation) of wave or sound …3

or

cannot be polarised …6

(*g*) State *Boyle's law.* **5, 1**
the pressure of a fixed mass of gas is inversely proportional to its volume …5
at constant temperature …1
or
$P \propto 1/V$ / PV is a constant / $P_1V_1 = P_2V_2$ …5
at constant temperature …1

(*h*) A gas has a volume of 330 cm^3 at 300 K. What is the volume of the gas at 450 K, if the pressure remains constant? **2×3**
$\frac{V_1}{T_1} = \frac{V_2}{T_2} / \frac{330}{300} = \frac{V}{450}$ …3
495 (cm^3) …3

(*i*) Copy the diagram in Figure 2 into your answer book and draw the magnetic field around the current carrying wire. **5, 1**
concentric circles around wire …5
arrows pointing anticlockwise …1

(*j*) Why is high voltage used to transmit electricity over long distances? **6**

reduces energy loss/reduces heat loss/reduces power loss/more economical/more efficient …6

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

when there is a change in magnetic flux // where magnetic field lines are cut …3

current induced / emf induced // …3

or

E …3

$= -N\frac{d\phi}{dt} / = -\frac{d\phi}{dt} / = \frac{d\phi}{dt}$ …3

(*l*) Give two ways of reducing energy losses in a transformer. **5, 1**

laminate the core, use a soft iron core, use core easily magnetised or demagnetised, reduce eddy currents, use a suitable shaped core, use wires or coils of low resistance, use thick wires (on the low voltage side), wind coils or wires tightly (around core), etc.

first correct… 5

second correct ..1

(*m*) What is radioactivity? **2×3**

spontaneous disintegration of (unstable) nucleus …3

with emission of fragments of matter or energy / with emission of (one or more types of) radiation …3

(*n*) Give two properties of beta particles. **5, 1**

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

first correct…5

second correct...1

(*o*) What is the main source of energy in the sun? **6**

(nuclear) fusion ...6

[fission …3]

Question 2

Define (i) velocity **2×3**
rate of change // speed …3
of displacement // in a given direction …3
[distance instead of displacement (–3)]

(ii) momentum. **3**
product of mass and velocity // *mv,* explain *m*, *v* …3
[omit to explain *m*, *v* (–1)]

What is kinetic energy? **3**
energy due to motion / (KE =)$\frac{1}{2}mv^2$ …3
[omit to explain *m*, *v* (–1)]

State *the principle of conservation of momentum*. **6**
(in a closed system of colliding bodies) where no external force acts total momentum is constant / total momentum before (a collision) is equal to total momentum after …6
[no external force acts omitted (–1)]
or
$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ / $m_1u_1 + m_2u_2 = (m_1 + m_2)\,v$, explain *m*, *v*
[omit to explain *m*, *v* (–1)]

Figure 3 shows an arrangement of two trolleys on a sloped track that you used to investigate the principle of conservation of momentum. Trolley A was set in motion at constant velocity and collided with trolley B that was stationary. Both trolleys then moved together at a new constant velocity.

Explain why the track was sloped. **3**
to eliminate or remove friction or to compensate for friction / to ensure (trolley) did not decelerate / to ensure (trolley ran at) constant speed / to ensure trolley moved freely …3
[reduce friction is sufficient]

How did you ensure that the two trolleys moved together after the collision? **3**
magnets or velcro or pin and cork, pin and blutack or similar, etc any one …3

Describe how the initial velocity of trolley A was measured. **6, 2×3 or 6, 6**
ticker tape timer or powder track timer // light gates // Fletcher's trolley …6
(measure) distance *s* // (measure) distance between gates *s* // (measure) distance corresponding to a number of 'waves' …3
(count) corresponding dots or spaces or powdered patches to get time *t* // (measure) times through two light gates // (count) number of 'waves' to get *t* …3
calculate $v = s/t$ …3
any two of last three points...2×3

or

motion sensor …6
computer …6

How do you know that trolley A, before the collision, did not accelerate down the track? **3**
timer dots evenly spaced / powder patches evenly spaced / time of passage through both light gates equal / waves evenly spaced on paper or waves not stretching / get $a = 0$ from $(v - u) / t$ …3
[may refer to previous answer, good diagram may be sufficient]
[because total momentum was conserved is not acceptable]

The mass of trolley B was increased and the process was repeated. The followed data were obtained.

	mass A kg	mass B kg	initial velocity of A m s^{-1}	final velocity of A and B joined m s^{-1}
Process 1	**0.200**	**0.300**	**0.160**	**0.063**
Process 2	**0.200**	**0.600**	**0.160**	**0.041**

Show that the data in the table are consistent with the principle of conservation of momentum. **5×3**

$m_1u_1 + m_2u_2 = (m_1 + m_2)v$ or any equivalent momentum expression e.g. $m_au_{a1} + m_bu_b = m_av_a + m_bv_b$ …3

$(0.200 \times 0.160) + (0.300 \times 0) = (0.500 \times 0.063)$ …3

$0.032 = 0.0315$ ...3

$(0.200 \times 0.160) + (0.600 \times 0) = (0.800 \times 0.041)$

$0.032 = 0.0328$ …3

(results of both tests show total) momentum is (almost) constant or constant within experimental error / true / consistent, etc …3

[In process 1 non-zero initial momentum for Trolley B (–3) and non-common or no final velocity for Trolleys A and B (–3). Where same errors made in Process 2 no further penalty.]

Calculate the kinetic energy lost in the collision between the trolleys during process 1. **3×3**

$KE = ½mv^2$ …3

$KE_1 – KE_2 = ½[0.200 \times (0.160)^2] – ½[0.500 \times (0.063)^2]$ / *subtracting two KE's* …3

$0.00256 – 0.0009922 = 0.0015678$ J [$0.002 – 0.00156$] …3

[either 0.00256 J or 0.0009922 J alone …6 maximum]

[no unit or incorrect unit (–1)]

[square shown but not included in calculation is a mathematical error (–1)]

What happened to this lost energy? **3**

(it was converted into) sound/heat/vibration …3

Question 3

(*a*) Refraction occurs when light changes direction as it passes from one medium into another.
State Snell's law of refraction. **2×3**

sine angle of incidence /sin*i* //(ratio of) sine angle of incidence to sine angle of refraction / $\frac{\sin i}{\sin r}$ …3

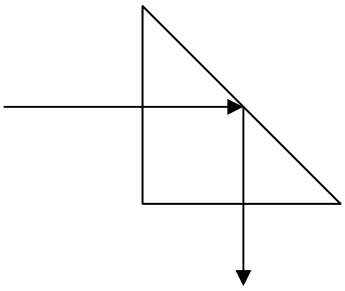
is proportional to sine angle of refraction / $\propto \sin r$ // is constant *or equal to refractive index or n or* μ …3
[sines omitted (– 3), reflection instead of refraction (– 3)] [no need to explain *i*, *r* etc]

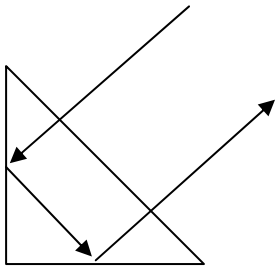
When does a ray of light *not* change direction when it passes from one medium into another? **6**
when the two media have the same (optical) density or refractive index, when the ray strikes the boundary (between the media) normally or at right angles any one…6

Explain the term *total internal reflection*. **6, 3**
when angle of incidence in more dense medium
exceeds critical angle
(all) the light is reflected back (into denser medium)

first correct…6
second correc...3

Draw a diagram to show that the direction of a ray of light can be changed by 90º using a 45º glass prism. **2×3**
ray enters short side of prism at right angles …3
ray leaves short side at right angles …3



[ (–1)]

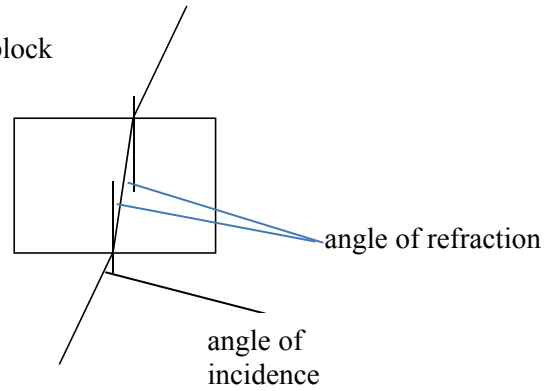
Question 3

(*b*) To verify Snell's law, a student measured the angles of incidence *i*, and the angles of refraction *r*, for a ray of light passing through a rectangular block of glass. The following results were obtained:

i/degrees	10.0	20.0	30.0	40.0	50.0	60.0	70.0
r/degrees	7.0	13.0	19.5	25.0	31.0	35.0	39.0

(*c*) Draw a diagram to show
(i) a ray of light striking the side of the glass block at an angle of incidence of 30°
(ii) the path of the light through the glass
(iii) the ray emerging from the block.
Label the refracted ray and the angle of refraction in your diagram. **4×3**

showing
angle of incidence labelled correctly …3
incident ray refracted towards normal upon entering block …3
emergent ray parallel to incident ray …3
either angle of refraction labelled correctly …3
[arrows not essential]



(*d*) Using the above data, draw a suitable graph on graph paper and explain how your graph verifies Snell's law. **6×3**

i/degrees	10.0	20.0	30.0	40.0	50.0	60.0	70.0
sin*i*	0.1736	0.3420	0.5000	0.6428	0.7660	0.8660	0.9397
r/degrees	7.0	13.0	19.5	25.0	31.0	35.0	39.0
sin*r*	0.1219	0.2250	0.3338	0.4226	0.5150	0.5736	0.6293

axes labelled sin*i* and sin*r* …3
suitable scales marked (must be scales < 1.0) …3
sines obtained in a table or list …3
five points plotted correctly …3
suitable straight line through points and the origin …3
straight line (when sin*i* plotted against sin*r*) through origin verifies Snell's law …3

[allow maximum 12 for ***i* versus *r*** as follows: 3 marks for axes labelled *i* and *r*, 3 marks for degree scales on both axes, 3 marks for five pairs of angles plotted correctly, 3 marks for suitable curve]

[allow maximum 9 where axes labelled **sin*i* and sin*r*** but angles are plotted]

(*e*) Use your graph find the refractive index of the glass. **3×3**
correct coordinates of two points marked on graph/angle graph makes with positive sense of *x*-axis …3
[points may include origin or original data points if line drawn goes through them]
find slope of graph using two points on the line or tan method …3

[$n = 1.58 – 1.38$] …3
[refractive index inverted (–3)]
[find correct refractive index using table or averaging instead of graph …max 8]
[allow marks for work done on any straight line from (*d*)]
[where curve produced in part (*d*) and tangent drawn allow max …6]

Question 4

(*a*) **Give two assumptions of the *kinetic theory of gases*.** **6, 3**

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

6 for first, 3 for second

Brownian movement provides evidence to support the kinetic theory of gases.
Describe how to demonstrate Brownian movement. **2×3**

smoke (in air) / pollen or other specified solid particle in specified liquid …3
viewed under microscope …3
[telescope (–1)]

What is observed? **3**

zig-zag straight line motion or vibration described or drawn / movement of visible particles due to collision with invisible particles / constant or continuous motion / rapid or random motion / collisions with walls of container …3

What is an *ideal gas*? **2×3**

obeys gas laws / Boyle's law / satisfies kinetic theory assumptions …3
at all temperatures and pressures …3
[temperature or pressure omitted (–1)]

A sample of helium gas is stored in a container of fixed volume.
How does the pressure on the walls of the container depend on the motion of the helium atoms inside? **2×3**

collisions (of particles with walls of container) or forces on walls (during collisions) // the faster the particles move …3
are the origin of pressure or create pressure // the greater the pressure …3

Describe how the motion of the helium atoms changes as the gas is cooled. **3**

(particles or helium atoms) move more slowly …3

At very low temperatures, how does helium differ in its behaviour from an ideal gas? **3**

ideal gases do not condense but helium does / ideal gas has zero volume at absolute zero but helium molecules have non-negligible volume at this low temperature / there are attractive forces or intermolecular forces in helium …3

Question 4

(*b*) **A mercury thermometer and a constant volume gas thermometer containing helium are both immersed in a container of warm water as shown in Figure 4.**
What is the thermometric property of
(i) a mercury thermometer **3**
height or length or volume (of liquid or mercury) …3

(ii) a constant volume gas thermometer? **3**
pressure (of a gas or of helium) …3

Why is a there a need for a standard thermometer? **2×3 or 6**
different thermometers read different temperatures / thermometers disagree /thermometers only agree at fixed points …3
when based on different thermometric properties ...3

or

to calibrate other thermometers …6

Why is the constant volume gas thermometer chosen as the standard? **3**
it is independent of substance used / it has a wide range / it is sensitive …3
[correct, accurate and precise are not acceptable answers]

Give one disadvantage of the constant volume gas thermometer. **3**
cumbersome, not portable, large, difficult to use, impractical, slow to reach thermal equilibrium, etc any one…3

The temperature of the warm water was calculated to be 330 K using measurements taken with the constant volume gas thermometer. The helium gas in the thermometer had a pressure of 130 kPa and a volume of 500 cm^3 at this temperature.
Calculate the number of moles of helium gas in the constant volume gas thermometer. **4×3**
$PV = nRT$ …3
$130000 \times (500 \times 10^{-6}) = n \times 8.3 \times 330$ …6
(n =) 0.024 …3
[any incorrect multiple of 0.024 (–3)] [(n =) 0.024 obtained by cancellation of two errors (–3)]
[no substitution for R (–3)]

Question 5

(*a*) Explain, in terms of electron transfer, what happens when an object becomes positively charged. **3**

electrons removed / electrons lost …3

State Coulomb's law of force between two point charges. **2×3 or 6**

force (between two point charges) is proportional to the product of the (two) charges …3

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

[square omitted (–3)][product omitted (–1)]

or

$F \propto \frac{Q_1 Q_2}{d^2}$ // $F = k\frac{Q_1 Q_2}{d^2}$ …6

[omit to explain F, Q, d //omit to explain F, Q d, k (–1)]

[square omitted (–3)]

When two point charges are separated by distance of 2 cm, the force between them is 2250 N. What is the size of the force between the two charges when the distance between them is changed to 4 cm? **2×3**

F/4 …3

562.5 (N) …3

[allow 1/4 …3] [allow 9,000 …3]

Make a copy in your answerbook of Figure 5, of a pear shaped conductor on an insulated stand. Show on your diagram how the charge is distributed over the conductor when it is charged positively. **2×3**

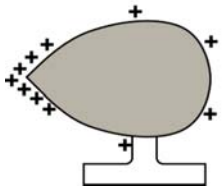
high density of positive charge at pointed end …3

low density of positive charge at curved end …3

[positive charges but evenly distributed …3]

[positive charge at one end only …3]

[negative charges correctly distributed …3]



What is an electric field? **2×3**

region in space around a charge …3

where other charges experience a force …3

[area (–1)]

Describe how to demonstrate the presence of an electric field pattern. **2×3**

correct arrangement of semolina or other non-ionic powdery solid, (olive) oil, (high voltage) direct current supply, conducting wires and conducting plates described or drawn …3

[each one omitted (–1)]

observation described or drawn …3

Question 5

(*b*) Define capacitance. **2×3 or 6**

ratio of charge // …3

to potential // …3

or

$$C = \frac{Q}{V}$$ …6

[omit to explain Q, V (–1)]

Give one use for a capacitor. **6**

tuning radio or TV stations, flash bulb in a camera, timer switches, to separate ac from dc, rectification, smoothing direct current, to reduce interference in radio signal, to prevent sparking in an induction coil, to start a motor, to store charge etc

any one…6

A charged parallel plate capacitor and an electroscope were arranged as shown in Figure 6. As the plates were moved farther apart

(i) what was observed **3**

leaves of electroscope moved farther apart or diverged more …3

(ii) how did the potential difference between the plates of the capacitor change **3**

potential difference increased …3

(iii) how did the capacitance of the parallel plate capacitor change? **3**

(capacitance) decreased …3

[(ii) and (iii) linked]

The capacitance of a parallel plate capacitor is 3.6 μF.
What charge is stored in this capacitor when it is attached to a 9.0 V battery? **2×3**

$C = \frac{Q}{V}$ / $Q = CV$ …3

$Q = 3.6 \times 10^{-6} \times 9.0 = 3.24 \times 10^{-5}$ C …3

[no unit or incorrect unit (–1)]

What is the capacitance of the capacitor if the common area of the plates is doubled without changing the distance between the plates? **6**

7.2 (μF) …6

[allow doubled, C ∝ A …5]

Question 6

Answer any two parts. **2×33**

Question 6 (*a*)
Define
(i) acceleration **2×3 or 6**
rate of change …3
of velocity / speed in a given direction …3
[rate of change of speed (–1)]

or

$\frac{v}{t}$ / $\frac{dv}{dt}$ / F/m …6
[omit to explain v and t or F and m (–1)]

(ii) force. **3**
causes (a mass) to accelerate / mass × acceleration / causes a body to move or change its velocity or direction / alters (or tends to alter) the motion of a body …3

[$F = ma$, m and a not explained (–1)]
[causes change of direction, push, pull, weight, friction, etc. – not sufficient]

State *Newton's second law of motion*. **2×3**
rate of change of momentum is proportional …3
to applied force and in same direction …3

Draw a labelled diagram of an arrangement of apparatus used to show that the acceleration of a moving body is proportional to the applied force. **3×3**
trolley on sloped track or on a smooth frictionless horizontal track, e.g. air track …3
attached to weights by string (passing over pulley) / attached to spring balance …3
timing using ticker tape timer, light gates, Fletchers trolley, etc …3
[no labels (–3)]

Calculate the force required to accelerate an object of mass 50 kg from rest to a velocity of 20 m s^{-1} in a distance of 80 m across a smooth horizontal surface. **3×3**
$v^2 = u^2 + 2as$ / $400 = 0 + (2\times a \times 80)$ …3
$a = 2.5$ (m s^{-2}) …3
$F = ma = 50 \times 2.5 = 125$ N …3
[no unit or incorrect unit (–1)]
[$F = ma$ alone, no marks; $50 \times 20 = 1000$ N, no marks]

Question 6 (*b*)

The photoelectric effect provides evidence for the particle behaviour of electromagnetic radiation and for the existence of photons.

What is a photon? **3**

packet or bundle or quantum of (light) energy / massless particle of (light) energy …3

Calculate the energy of a photon of infrared radiation that has a wavelength of 1.4×10^{-5} m. **4×3**

$c = f\lambda$ or $f = \frac{c}{\lambda}$ …3

$f = \frac{3\times10^{8}}{1.4\times10^{-5}} = 2.14 \times 10^{13}$ (Hz) …3

$E = hf$ …3

$E = 6.6 \times 10^{-34} \times 2.14 \times 10^{13} = 1.41 \times 10^{-20}$ J …3

[no unit or incorrect unit (–1)]

Electrons are released by the photoelectric effect when ultraviolet light shines on a freshly cleaned zinc plate but electrons are *not* released when infrared radiation shines on the zinc plate.

Explain why electrons are released from zinc by ultraviolet radiation but not by infrared radiation. **6**

frequency of ultraviolet light high enough / frequency of infrared radiation not high enough / photons of ultraviolet have sufficient energy / photons of infrared radiation have insufficient energy / threshold energy not exceeded by infrared photons …6

[ultraviolet suitable / infrared unsuitable …3]

Name a phenomenon that provides evidence for the wave nature of light. **3**

interference / diffraction // polarisation // Doppler effect …3

Describe how you could demonstrate the phenomenon you have named. **3×3**

monochromatic light source or laser and Young's slits or diffraction grating // light source and two pieces of Polaroid // stationary monochromatic light source or laser, rotating mirror and detector …3

correct arrangement …3

interference pattern or diffraction pattern described or drawn // effect of rotation of one piece of Polaroid by 90º // frequency of reflected light differs from frequency of stationary light source …3

[allow speed gun using microwaves or red shift of distant galaxies as a demonstration of Doppler effect]

Question 6 (*c*)

What is an electric current? **3**
flow of charge / flow of electrons / flow of ions …3

State Ohm's law. **2×3**
current is proportional or $I \propto$ //potential difference is proportional or $V \propto$ // V = …3
to potential difference or V // to current or I // IR …3
[omit at constant temperature (–1), omit to explain terms (–1)]

Figures 7 and 8 show two circuits, each containing two filament lamps, each of which has a resistance of 4 Ω. Each circuit is connected to a 12 V battery.

Calculate the effective resistance of each circuit. **3×3**
$R = R_1 + R_2 = 4 + 4 = 8\ \Omega$ …3

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{4} + \frac{1}{4} = \frac{1}{2}$$ …3

$R = 2\ \Omega$ …3
[correct unit must appear here in at least one of these answers; no unit or incorrect unit in (–1)]
[answers reversed (–1)] [error in fractions (–1)]

Calculate the current flowing through each lamp
(i) in the series circuit **2×3**

$$I = \frac{V}{R}$$ …3

$$= \frac{12}{8} = 1.5\ \text{A}$$ …3

(ii) in the parallel circuit. **2×3**

$$I = \frac{V}{R}$$ …3

$$= \frac{12}{2} = 6A$$ …3

[correct unit must appear here in at least one of these current answers; no unit or incorrect unit in (–1)]

In which circuit do the lamps light brightest? **3**
parallel circuit / second circuit / circuit where current through bulb is bigger …3

Question 6 (*d*)

Figure 9 illustrates the nuclear fission of a uranium-235 nucleus when it was struck by a neutron and disintegrated according to the following nuclear equation.

$^{235}_{X}U + {}^{1}_{0}n \rightarrow {}^{93}_{Y}Rb + {}^{Z}_{55}Cs + 3{}^{1}_{0}n$ + energy

What are the values of X, *Y* and *Z*? **3×3**

X = 92 …3

Y = 37 …3

Z = 140 …3

Explain how the fission of one uranium-235 nucleus could lead to a chain reaction in a uranium sample. **2×3**

at least one neutron produced …3

for every uranium nucleus split …3

[accept Rb and Cs split to release more neutrons that cause further fission]

What is meant by mass-energy conservation in nuclear reactions? **2×3**

when a small amount of mass is destroyed // mass-energy of products is equal …3

energy is released correspondingly or according to $E = mc^2$// to mass-energy of reactants …3

[$E = mc^2$ only ....3]

Calculate the mass lost when one uranium-235 nucleus undergoes fission to release 1.08×10^{-12} J of energy. **2×3**

$E = mc^2 / m = \frac{E}{c^2}$ …3

$m = \frac{1.08 \times 10^{-12}}{(3.0 \times 10^{8})^2}$ $= 1.2 \times 10^{-29}$ kg …3

[no unit or incorrect unit (–1)]

Give one application of nuclear fission. **6**

electricity generation, nuclear power station or nuclear energy station, production of radioactive isotopes (for medical use, etc), weapon or bomb …6

[nuclear power, nuclear energy …3]

Question 7

Any eleven parts. **11×6**

(*a*) What is the (i) the atomic number, (ii) the mass number, of an atom of $^{56}_{26}Fe$? **2×3**

26 …3
56 …3
[atomic number is the number of protons and mass number is the number of protons and neutrons …3]
[reversed …3]

(*b*) Suggest a suitable term to use as a heading for Column A and a suitable term for Column B in the table on the right. **2×3**

CARBON	
_____A_____	_____B_____
Diamond	Carbon-12
Graphite	Carbon-13
	Carbon-14

A = allotropes / crystalline forms …3
B = isotopes …3
[reversed …3]

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

(*d*) A platinum rod was cleaned in hydrochloric acid, dipped into a salt of a metal and held in the flame of a Bunsen burner as shown in Figure 10. What colour flame was observed when the salt used was (i) potassium chloride, (ii) sodium chloride? **2×3**
(i) purple / lilac …3
(ii) yellow / amber / orange …3
[colours reversed …3]

(*e*) Why is a metal a good conductor of electricity? **2×3**
(valence) electrons / (free) electrons …3
move / carry the current / free …3

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

(*g*) What is (i) the conjugate acid of H_2O, (ii) the conjugate base of NH_4^+ ? **2×3**
(i) H_3O^+ …3
(ii) NH_3 …3
[OH^- **and** NH_5^{2+} …3]
[any incorrect charge (–1)]

(*h*) What two types of acid-base titration use phenolphthalein as the suitable indicator? **2×3**
strong acid - strong base …3
strong base - weak acid …3

(*i*) Sodium metal reacts vigorously in cold water. What are the products of this reaction? **5, 1**
hydrogen gas / H_2
sodium hydroxide / NaOH

first correct…5
second correct...1

(*j*) Calculate the percentage of oxygen in silicon dioxide (SiO_2). **2×3**

(M_r) = 60 …3

$\frac{32}{60} \times 100 = 53.33\ \%\ (53\%)$ …3

(*k*) From the following list of hydrides select (i) an acidic substance, (ii) a substance that is gaseous at room temperature.

H_2S NH_3 MgH_2 NaH

5, 1

(i) H_2S
(ii) H_2S or NH_3

first correct…5
second correct...1

(*l*) Define *heat of solution*. **2×3**

heat or energy released or absorbed when one mole of a substance / heat or energy involved when one mole of a substance …3
is dissolved in (excess) water …3
[energy evolved (–1)]
[accept reference to solution or solvent where water not mentioned unless another solvent specified]

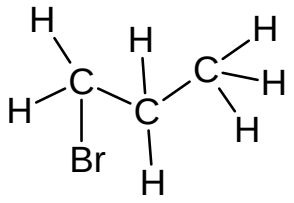
(*m*) Name the two substances always formed when an organic compound is burned in excess oxygen. **5, 1**

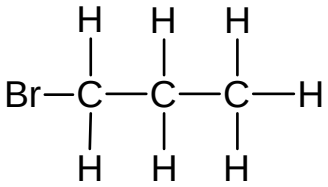
water
carbon dioxide

first correct…5
second correct...1

(*n*) Draw the molecular structure of the compound 1-bromopropane, a solvent used in some liquid correction fluids like that shown in Figure 11. **6**

$BrCH_2CH_2CH_3$ …6





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

(*o*) Name the two aromatic compounds (i) and (ii), shown in Figure 12, that occur in small amounts in petrol. **5, 1**

(i) benzene
(ii) methylbenzene /toluene
[reversed …3]

first correct…5
second correct...1

Question 8

(*a*) What is an atomic orbital? **2×3**

region in space (around the nucleus) …3

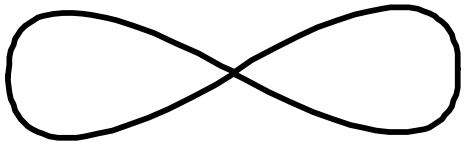
where there is a high probability of finding an electron / where an electron is most likely to be found ….3

[area (–1)]

Draw the structure of a p-orbital. **3**

…3

[accept a set of three p-orbitals]



Write the *s*, *p* electron configuration of a chlorine atom in its ground state. **6**

$1s^2 2s^2 2p^6$ …3

$3s^2 3p_x^2 3p_y^2 3p_z^1$ / $3s^2 3p^5$ ….3

The four quantum numbers of an electron in a chlorine atom are 3, 1, 1, ½. What information about the electron is given by (i) the first quantum number **3**

(main) energy level occupied / shell occupied / 3rd shell occupied (by highest energy electron) …3

(ii) the fourth quantum number? **3**

the spin (of the electron) …3

(*b*) Define electronegativity. **2×3**

measure of attraction / relative attraction / measure of the force of attraction (an atom in a molecule has) …3

for shared pair of electrons / for electrons in a covalent bond …3

[force of attraction (an atom in a molecule has) (–1)]

Give the name or formula of a compound made from two different elements of the first eighteen elements that has pure covalent bonding. **3**

PH_3 or phosphine / CS_2 or carbon disulphide / any binary compound where difference between the electronegativities of its elements ≤ 0.05 …3

[two elements correctly selected, name or formula incorrect (–1)]

What type of bonding occurs in the compound BeH_2? **3**

polar covalent …3

[omit polar (–1), omit covalent (–1)]

What is the shape of a BeH_2 molecule? **3**

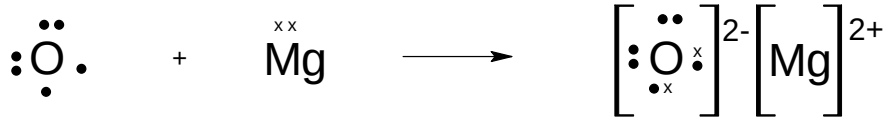
linear …3

[diagram can suffice]

What type of bond is formed when magnesium and oxygen combine? **3**

ionic …3

Use diagrams to show the formation of the bond in magnesium oxide. **3×3**



atoms correct …3

oxygen ion product with dinegative charge …3

magnesium ion product with dipositive charge …3

[diagram showing two electrons transferring from magnesium atom to oxygen atom but no ions …9]

[diagram of $Mg^{2+}O^{2-}$ in a crystal lattice …6 maximum]

Question 8 (*c*)

Define the first ionisation energy of an element. **1, 3, 2**
minimum …1
energy required to remove outermost or most loosely bound electron …3
completely from a mole of neutral gaseous or isolated atoms …2
[minimum omitted (–1), completely omitted (–1), neutral omitted (–1), gaseous or isolated omitted (–1), one mole omitted (–1)]

Figure 13 represents the first ionisation energy values of the elements in the third period of the periodic table.
Explain the general increase across the period. **2×3**
(outermost electron is increasingly difficult to remove because of)
increasing nuclear charge / increasing atomic number …3
decreasing atomic radius / (3rd) shell contracts …3

Why are the values for magnesium and for phosphorus higher than expected? **6**
(outermost electron is removed from) a stable electron configuration /
magnesium has a full outer **subshell** or **sublevel** / phosphorus has a half-filled outer **subshell** or **sublevel /** both electron configurations given correctly …6
[stable …3]

Question 9

A student determined the concentration of a hydrochloric acid solution by titration with 25.0 cm^3 portions of a primary standard solution of anhydrous sodium carbonate.

(*a*) Explain the underlined term. **2×3**

pure / stable / high molecular mass / solid / exact mass of which can be weighed out or can be weighed accurately / to give solution of known concentration any two…2×3

Describe how the student could have prepared 500 cm^3 of a 0.05 M primary standard solution from 2.65 g of pure anhydrous powdered sodium carbonate, supplied on a clockglass. **5×3**

using deionised water or distilled water …3

(rinse) powder into beaker / (rinse) sodium carbonate into beaker …3

stir (to dissolve) …3

heat to complete dissolving but cool completely or to room temperature before zeroing or completing the procedure …3

using a funnel transfer (contents of beaker) …3

to (500 cm^3) volumetric flask …3

rinse beaker with (deionised) water and (add rinsings to flask) …3

add (deionised) water to bring volume close to mark …3

then add (deionised) water dropwise / then add water using a pipette / then add water using a wash-bottle ...3

until bottom of meniscus lies on mark …3

stopper and mix thoroughly / stopper and invert several times …3

any five…5×3

(*b*)

(i) How was a burette rinsed before filling it with the hydrochloric acid solution? **2×3**

with deionised water …3

with the hydrochloric acid solution / with the solution it will contain …3

(ii) Why was a small funnel used when filling the burette? **3**

to avoid spilling / because of narrow opening or neck (of burette) …3

(iii) Why was the funnel removed before adjusting the liquid to the zero mark? **3**

to avoid drops falling from stem of funnel and changing liquid level after zeroing / so stem of funnel doesn't raise level of liquid in burette / to ensure accurate reading …3

(iv) Describe how the liquid level in the burette was adjusted to the zero mark. **3**

open tap and allow liquid to flow (until bottom of meniscus lies on zero mark) …3

[allow add HCl solution using dropper (until bottom of meniscus lies on zero mark) but HCl not mentioned (–1)]

(v) Why was a pipette filler used to fill the pipette with 25.0 cm^3 sodium carbonate solution? **3**

for safety / to avoid swallowing solution (being pipetted) / hygiene …3

Question 9

(*c*) Name a suitable indicator for this titration. **3**

methyl orange …3

State the colour change observed in the conical flask at the end point of this titration. **2×3**

yellow (orange) to …3

(orange) pink / red …3

[colours reversed …3]

[orange to orange not acceptable]

[if phenolphthalein is given as indicator accept pink to colourless for …6 and colours reversed …3]

[if litmus is given as indicator accept blue to red for …6 and colours reversed …3]

(*d*) Write a balanced equation for this titration reaction. **2×3**

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

/

$$2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2CO_3$$

correct reactants and products …3

balanced …3

[NaCl and H_2O products …3]

(*e*) On average 21.2 cm^3 of hydrochloric acid was required to neutralise 25.0 portions of the 0.05 M sodium carbonate solution.

Calculate the concentration of the hydrochloric acid solution in

(i) moles per litre **2×3**

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

$\frac{21.2 \times M_1}{2} = \frac{25.0 \times 0.05}{1} \Rightarrow M_1 = 0.1179$ (M) = [0.1179 - 0.12 (M)] …3

[apply no penalty if n_1: n_2 ratio in (*e*) is consistent with an incorrect balanced equation given in (*d*);
$M_1 = 0.0589$(M) = [0.0589 - 0.06 (M)] is consistent with n_1: n_2 ratio 1:1]

[if (*d*) not attempted and incorrect ratio used in (*e*) (–1)]

(ii) grams per litre. **2×3**

(M_r) = 36.5 …3

$0.1179 \times 36.5 = 4.30$ (g l^{-1}) = [4.30 – 4.38 (g l^{-1})] …3

[2.15 (g l^{-1}) = [2.15 – 2.19 (g l^{-1})] is consistent with n_1: n_2 ratio 1:1]

Question 10

(*a*) Define oxidation. **3**
loss of electrons / addition of oxygen / loss of hydrogen / increase in oxidation number …3

What is the electrochemical series? **2×3**
lists the (common) metals or elements …3
in order of their decreasing ease of oxidation or decreasing ease of loss of electrons or reactivity or electrode potential …3
[word decreasing omitted or word increasing used in error (–1)]

In what order do the common metals copper, aluminium and iron occur in the electrochemical series? **3**
aluminium iron copper …3
[reversed (–1)]

A freshly sanded piece of aluminium is placed into a solution of copper sulfate in a beaker. The following reaction occurs.

$$2Al + 3CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu$$

What changes are observed as the reaction proceeds? **2×3**
blue colour of solution fades / aluminium reacts or dissolves / copper metal appear or reddish solid appears any two …2×3

Identify
(i) the substance oxidised **3**
aluminium …3

(ii) the oxidising reagent. **3**
copper ions or copper sulfate or $CuSO_4$ …3

Why must the aluminium be first cleaned with sandpaper? **3**
(surface) oxide prevents reaction / to remove oxide layer or tarnish or corrosion / to expose metal …3

Would a chemical reaction occur if a piece of freshly sanded iron were placed into a solution of aluminium sulfate? **3**
No …3

Justify your answer. **3**
Iron less reactive than aluminium / iron less easily oxidised than aluminium / iron below aluminium on electrochemical series / aluminium above iron on electrochemical series …3
[check answer is consistent with order of metals given earlier]

Question 10 (*b*)

Aluminium oxide, Al_2O_3, purified in Ireland, is exported to Russia for electrolysis to produce pure aluminium metal and oxygen gas as a co-product. The electrolysis of the molten aluminium oxide is carried out using inert electrodes in cells like that shown in Figure 14.

Explain the underlined terms. **2×3, 6**
(electrolysis is a) chemical change …3
caused by electric current …3

(inert electrodes) do not participate in electrolysis reactions …6
[example …3]

How does molten aluminium oxide conduct electricity? **3**
movement of ions …3

The cathode reaction is $Al^{3+} + 3e^- \rightarrow Al$.
Write the corresponding anode reaction where oxygen is produced. **2×3**
$O^{2-} \rightarrow O + 2e^- \rightarrow ½O_2$ **or** $O^{2-} - 2e^- \rightarrow ½O_2$ or any multiple of these
reactants and products correct …3
[omit $\rightarrow O_2$ (–1)]
balanced …3

A current of 220 000 A is passed through the molten aluminium oxide in a cell.
Calculate:
(i) the charge that flows in ten minutes **3**
$Q = It = 220\,000 \times 10 \times 60 = 1.32 \times 10^8$ C …3
[incorrect units / no units (–1)]

(ii) the mass of aluminium metal produced in ten minutes. **3×3**
$(1.32 \times 10^8 \div 96485) = 1368.10$ moles electrons [1367.9 - 1368.1] …3
$1368.10 \div 3 = 456.03$ (moles aluminium) [455.97 – 456.03] …3
$456.03 \times 27 = 12313$ (g) [12310 – 12313] …3

[If first step inverted do not award the first 3 marks.]

Question 11

The hydrocarbons methane and ethene are important gaseous organic chemicals. Methane is the first member of the alkane homologous series and is a saturated compound. Ethene, an alkene, is unsaturated.

(*a*) Explain the underlined terms. **4×3**

(hydrocarbons contain the elements) carbon and hydrogen only …3

[only omitted (–1)]

(organic chemicals) are compounds of carbon (with the exception of some simple carbon compounds) …3

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

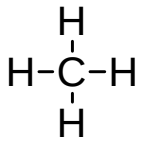
(*b*) Give a major use for *either* methane *or* for ethene. **3**

methane: fuel / hydrogen production / steam reforming
ethene: polymer manufacture, ripening fruit, chemical industry raw material

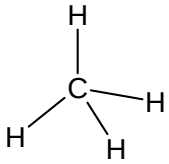
any one …3

(*c*) Draw the molecular structures of (i) methane, (ii) ethene. **6, 3**

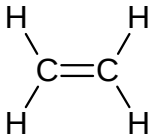
(i)



or



(ii)



first correct…6

second correct…3

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

(*d*) What is the difference between a saturated and an unsaturated organic compound? **6**

saturated compounds have single bonds /unsaturated compounds have double or triple bonds …6
[omit between carbon atoms (–1)]

Name a reagent that could be used in a test to show that ethene is unsaturated. **3**

bromine /acidified potassium permanganate …3

[acidified omitted (–1)]

What colour change confirms the unsaturation of ethene? **2×3**

yellow or orange or brown or red / purple …3
to colourless …3
[clear unacceptable][colours reversed …3]

(*e*) What are the products when one mole of chlorine and one mole of methane react? **2×3**

chloromethane / CH_3Cl …3
[inconsistent name and formula if one correct (–1)]
hydrogen chloride / HCl …3
[hydrochloric acid (–1)]

What is the essential condition for this reaction to occur? **3**

ultraviolet light / (bright) sunlight …3

Is this a substitution reaction or an addition reaction? **3**

substitution …3

Justify your answer. **3**

two products / hydrogen in methane **replaced** by chlorine / alkanes undergo substitution reactions / only alkenes or alkynes undergo addition reactions, etc …3

(*f*) Describe with the aid of a labelled diagram how you could convert ethanol to ethene. **4×3**

ethanol and aluminium oxide // ethanol and sulfuric acid or H_2SO_4 …3
test tube on side, glass wool to hold ethanol // flask, air condenser …3
heat aluminium oxide with Bunsen // heat flask with Bunsen …3
collect ethene gas over water …3
[no diagram max…9]

Question 12

Answer any three parts. **3×22**

Question 12 (*a*)

Figure 15 shows four of the energy levels of the electron in a hydrogen atom. E_1 is the ground state and E_2, E_3 and E_4 are the excited states.

Define energy level. **2×2**
definite or fixed or specific energy …2
of an electron in an atom …2

Explain

(i) how the electron can be promoted from a lower energy level to a higher one, e.g. E_1 to E_3 **3**
heat / electricity / electromagnetic radiation …3

(ii) why the electron doesn't remain in any of the excited states E_2, E_3 or E_4 **3**
excited state unstable or temporary …3

(iii) why the electron cannot occupy the spaces between the energy levels **3**
electron must be in an energy level / electron not permitted in between energy levels /
electron energies quantised / spaces between are unstable …3

(iv) what happens when an electron falls from a higher energy level to a lower level **6**
it emits the difference in energy between the two energy levels / emits hf / emits $E_2 - E_1$
as electromagnetic radiation/ as light / photon emitted …6
[hf not explained (–1)]

(v) the difference observed when an electron falls from E_4 to E_2 instead of from E_3 to E_2. **3**
more energy emitted / hf bigger / higher frequency light emitted / lower wavelength light emitted /
different frequencies or wavelengths or colours, etc …3

Question 12 (*b*)

Distinguish between a strong acid and a weak acid according to the Brønsted-Lowry theory. **2×3**
strong acids are good proton donors …3
weak acids are poor proton donors …3
[fully dissociated, slightly or weakly dissociated (–1) once]
[accept partially dissociated]

Write an expression to define pH. **3**
(pH =) $-\log_{(10)}[H^+]$ / (pH =) $-\log_{(10)}[H_3O^+]$ …3

What is the relationship between pH and pOH? **3**
pH + pOH = 14 …3

Calculate the pH of

(i) a 0.2 M solution of H_2SO_4 **2×2**
0.4 (moles) …2
(pH =) $-\log_{(10)}[H^+] = -\log_{(10)}[0.4] = 0.40$ …2
[0.70 …2]

(ii) a 0.2 M solution of KOH. **2×3**
(pOH =) $-\log_{(10)}[OH^-] = -\log_{(10)}[0.2] = 0.70$ …3
14 – 0.70 = 13.3 …3

Question 12 (*c*)

When alcohol in the form of ethanol (C_2H_5OH) is consumed by a person, it is converted to ethanal (CH_3CHO) and then to ethanoic acid (CH_3COOH) and finally to carbon dioxide and water which are expelled by the body.

The reactions that occur are:

$$C_2H_5OH \rightarrow CH_3CHO + H_2$$
$$H_2 + \tfrac{1}{2}O_2 \rightarrow H_2O$$
$$CH_3CHO + \tfrac{1}{2}O_2 \rightarrow CH_3COOH$$
$$CH_3COOH + 2O_2 \rightarrow 2H_2O + 2CO_2$$

If the person consumed a bottle of wine, containing 92 g ethanol, calculate

(i) the number of moles of ethanol in a bottle of wine **2×3**

$(M_r) = 46$ …3

$\frac{92}{46} = 2$ (moles) …3

(ii) the number of moles of carbon dioxide produced when the alcohol is processed in the body **3**

4 (moles)

[2 (moles) (–1)] …3

(iii) the volume of carbon dioxide exhaled when measured at standard temperature and pressure **3**

$4 \times 22.4 = 89.6$ (litres) or 89 600 (cm^3) …3

[$PV = nRT$ approach acceptable but unit must be consistent with answer, otherwise (–1)]

(iv) the total mass of water produced in the body in the processing of the alcohol. **3×2**

6 (moles) …2

[3 (moles) (–1)]

$(M_r) = 18$ …2

$6 \times 18 = 108$ (g) …2

(v) the number of molecules of oxygen required for the last reaction of the process. **2×2**

4 (moles) / 2 (moles) …2

$4 \times (6 \times 10^{23}) = 2.4 \times 10^{24}$ / $2 \times (6 \times 10^{23}) = 1.2 \times 10^{24}$ …2

Question 12 (*d*)

State *Hess's law.* **2×3**
heat change for a reaction / heat involved when a reaction takes place …3
independent of path taken / depends only on initial and final states …3
[heat evolved (–1)]

Consider the following reactions:

$$\mathbf{Fe_2O_{3\,(g)} + 3CO_{(g)} \rightarrow 2Fe + 3CO_{2\,(g)}} \qquad \mathbf{\Delta H = -26.3\ kJ\ mol^{-1}}$$

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

$$\mathbf{CO_{(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow CO_{2\,(s)}} \qquad \mathbf{\Delta H = -283.5\ kJ\ mol^{-1}}$$

Use Hess's law and the heats of reaction listed above to calculate the heat of reaction for the extraction of iron metal from one of its ores by coke, according to the following reaction:

$$\mathbf{2Fe_2O_{3\,(g)} + 3C_{(s)} \rightarrow 4Fe + 3CO_{2\,(g)}}$$ **4×3**

$2Fe_2O_{3\,(g)} + 6CO_{(g)} \rightarrow 4Fe + 6CO_{2\,(g)}$ $\Delta H = -52.6\ kJ\ mol^{-1}$ …3

$3C_{(s)} + 3O_{2\,(g)} \rightarrow 3CO_{2\,(g)}$ $\Delta H = -1180.5\ kJ\ mol^{-1}$ …3

$6CO_{2\,(s)} \rightarrow 6CO_{(g)} + 3O_{2\,(g)}$ $\Delta H = 1701.0\ kJ\ mol^{-1}$ …3

$2Fe_2O_{3\,(g)} + 3C_{(s)} \rightarrow 4Fe + 3CO_{2\,(g)}$ $\Delta H = +467.9\ kJ\ mol^{-1}$ …3

Is energy absorbed or released as this reaction proceeds? **2**
absorbed …2

Justify your answer. **2**
endothermic /ΔH positive …2
[if ΔH negative therefore exothermic …2 or if ΔH positive therefore endothermic …2]