

Questions

**48 (16 per subject)**

Marks

**180 (60 per subject)**

Time

**3 hours**

Negative marking

**–1 in Sections 1, 2, 4**

| Part                | Section                                                                | Questions | Q. No.   |
|---------------------|------------------------------------------------------------------------|-----------|----------|
| Part I: Mathematics | Mathematics – Section 1: One correct option (+3, –1)                   | 4         | 1 to 4   |
| Part I: Mathematics | Mathematics – Section 2: One or more correct options (+4, partial, –1) | 4         | 5 to 8   |
| Part I: Mathematics | Mathematics – Section 3: Numerical value (+4, 0)                       | 4         | 9 to 12  |
| Part I: Mathematics | Mathematics – Section 4: Matching List Sets (+4, –1)                   | 4         | 13 to 16 |
| Part II: Physics    | Physics – Section 1: One correct option (+3, –1)                       | 4         | 17 to 20 |
| Part II: Physics    | Physics – Section 2: One or more correct options (+4, partial, –1)     | 4         | 21 to 24 |
| Part II: Physics    | Physics – Section 3: Numerical value (+4, 0)                           | 4         | 25 to 28 |
| Part II: Physics    | Physics – Section 4: Matching List Sets (+4, –1)                       | 4         | 29 to 32 |
| Part III: Chemistry | Chemistry – Section 1: One correct option (+3, –1)                     | 4         | 33 to 36 |
| Part III: Chemistry | Chemistry – Section 2: One or more correct options (+4, partial, –1)   | 4         | 37 to 40 |
| Part III: Chemistry | Chemistry – Section 3: Numerical value (+4, 0)                         | 4         | 41 to 44 |
| Part III: Chemistry | Chemistry – Section 4: Matching List Sets (+4, –1)                     | 4         | 45 to 48 |

### Instructions

1. This is Paper 1. It has 48 questions: Mathematics (Q1–16), Physics (Q17–32) and Chemistry (Q33–48). Each subject has four sections, in the order of the official JEE (Advanced) 2026 Paper 1.
2. Section 1 (4 questions per subject): four options, ONLY ONE correct. +3 if only the correct option is chosen; 0 if unanswered; –1 in all other cases.
3. Section 2 (4 questions per subject): ONE OR MORE of the four options (A)–(D) may be correct. +4 if all the correct options and no wrong option are chosen; +3 if all four options are correct and only three are chosen; +2 if three or more options are correct and only two are chosen, both correct; +1 if two or more options are correct and only one is chosen, and it is correct; 0 if unanswered; –1 in all other cases.
4. Section 3 (4 questions per subject): the answer is a NUMERICAL VALUE. If it has more than two decimal places, truncate/round it off to two decimal places. +4 if correct; 0 in all other cases (no negative marking).
5. Section 4 (4 questions per subject): each Matching List Set has List-I (P, Q, R, S) and List-II (1)–(5), and ONE of the four options is correct. +4 if only the correct option is chosen; 0 if unanswered; –1 in all other cases.
6. Maximum marks 180 (60 per subject). Time 3 hours. Calculators, log tables and other aids are not allowed.
7. In this printed paper, write Section 2 and Section 3 answers in the box under the question. The answer key shows "–" for them; their answers are given at the start of each solution.

This is an AglaSem practice paper written on the official JEE (Advanced) 2026 Paper 1 pattern (48 questions, 180 marks, 3 hours) and the current JEE (Advanced) syllabus. It is not an official IIT / Joint Admission Board paper, and its questions are original. The real paper is computer-based and also has Paper 2 on the same day.

Mathematics – Section 1: One correct option (+3, –1)

- Let  $S$  be the set of all complex numbers  $z$  satisfying  $|z - 3 - 4i| = 2$ . For  $z \in S$ , the expression  $|z|^2 + |z - 6 - 8i|^2$ :  
 (A) is constant and equals 54  
 (B) is constant and equals 58  
 (C) has greatest value 58 and least value 50  
 (D) has greatest value 66 and least value 50
- Let  $P(x)$  be a polynomial of degree 3 such that  $P(k) = 1/k$  for  $k = 1, 2, 3, 4$ . Then  $P(5)$  equals:  
 (A)  $2/5$  (B) 0  
 (C)  $-1/5$  (D)  $1/5$
- A fair die is rolled repeatedly until a six appears for the first time. The probability that the number of rolls needed is even is:  
 (A)  $1/2$  (B)  $5/12$   
 (C)  $5/11$  (D)  $6/11$
- The value of  $\lim_{x \rightarrow 0} [(1+x)^{1/x} - e]/x$  is:  
 (A) 0 (B)  $-e$   
 (C)  $e/2$  (D)  $-e/2$

Mathematics – Section 2: One or more correct options (+4, partial, –1)

- Let  $f(x) = x^3 - 3x + 1$ . Which of the following statements is/are correct? (One or more options may be correct.)  
 (A) The product of the real roots of  $f(x) = 0$  is 1.  
 (B)  $f(x) = 0$  has exactly one root in the interval  $(0, 1)$ .  
 (C)  $2 \cos(2\pi/9)$  is a root of  $f(x) = 0$ .  
 (D) The sum of the squares of the roots of  $f(x) = 0$  is 6.
- Consider the lines  $L_1: (x-1)/2 = (y-2)/3 = (z-3)/4$  and  $L_2: (x-2)/3 = (y-4)/4 = (z-5)/5$ . Which of the following statements is/are correct? (One or more options may be correct.)  
 (A)  $L_1$  and  $L_2$  are skew lines.  
 (B) The shortest distance between  $L_1$  and  $L_2$  is  $1/\sqrt{6}$ .  
 (C) The plane containing  $L_1$  and parallel to  $L_2$  is  $x - 2y + z = 0$ .  
 (D) The perpendicular distance of the origin from the plane in (C) is  $1/\sqrt{6}$ .
- For  $n \geq 0$ , let  $I_n = \int_0^{\pi/2} \sin^n x \, dx$ . Which of the following statements is/are correct? (One or more options may be correct.)  
 (A)  $I_n = ((n-1)/n) \cdot I_{n-2}$  for every  $n \geq 2$ .  
 (B)  $I_5 = 16/15$ .  
 (C)  $n \cdot I_n \cdot I_{n-1} = \pi/2$  for every  $n \geq 1$ .  
 (D)  $\lim_{n \rightarrow \infty} I_n/I_{n+1} = 1$ .

8. For the ellipse  $x^2/9 + y^2/5 = 1$ , which of the following statements is/are correct? (One or more options may be correct.)
- (A) Its eccentricity is  $2/3$ .
- (B) The tangent at the point  $(2, 5/3)$  meets the major axis at a point lying on the auxiliary circle  $x^2 + y^2 = 9$ .
- (C) The area of the quadrilateral formed by the tangents at the four ends of the two latera recta is 27 square units.
- (D) The sum of the distances of any point of the ellipse from the two foci is  $2\sqrt{5}$ .

### Mathematics – Section 3: Numerical value (+4, 0)

9. The number of functions  $f : \{1, 2, 3, 4, 5\} \rightarrow \{1, 2, 3, 4, 5\}$  such that  $f(f(x)) = x$  for every  $x$  is \_\_\_\_.
10. Let  $[t]$  denote the greatest integer less than or equal to  $t$ . The value of  $\int_0^2 [x^2] dx$ , correct to two decimal places, is \_\_\_\_.
11. Let  $\omega = \cos(2\pi/7) + i \sin(2\pi/7)$ . The value of  $|1 + \omega + \omega^2 + \omega^4|^2$  is \_\_\_\_.
12. The number of  $2 \times 2$  matrices whose entries are all from the set  $\{0, 1, 2\}$  and whose determinant is zero is \_\_\_\_.

### Mathematics – Section 4: Matching List Sets (+4, -1)

13. Match each entry in List-I to the correct entry in List-II and choose the correct option.

List-I

(P)  $\lim_{x \rightarrow 0} (1 - \cos 2x)/x^2$

(Q) The number of points at which  $f(x) = |x^2 - 1| + |x|$  is not differentiable on  $\mathbb{R}$

(R)  $\int_0^{\pi/2} (\sin x - \cos x)/(1 + \sin x \cos x) dx$

(S) The remainder when  $2^{2027}$  is divided by 7

List-II

(1) 0; (2) 1; (3) 2; (4) 3; (5) 4

(A) (P)→(3), (Q)→(4), (R)→(1), (S)→(5)

(B) (P)→(2), (Q)→(4), (R)→(1), (S)→(5)

(C) (P)→(3), (Q)→(4), (R)→(2), (S)→(4)

(D) (P)→(3), (Q)→(3), (R)→(2), (S)→(5)

14. Match each entry in List-I to the correct entry in List-II and choose the correct option.
- List-I
- (P) The radius of the circle  $x^2 + y^2 - 4x + 6y - 12 = 0$
- (Q) The length of the focal chord of the parabola  $y^2 = 4x$  that makes an angle of  $45^\circ$  with its axis
- (R) The perpendicular distance of a focus of the hyperbola  $x^2/16 - y^2/9 = 1$  from either of its asymptotes
- (S) The length of the common chord of the circles  $x^2 + y^2 = 25$  and  $x^2 + y^2 - 8x + 7 = 0$
- List-II
- (1) 3; (2) 4; (3) 5; (4) 6; (5) 8
- (A) (P)→(4), (Q)→(5), (R)→(1), (S)→(3)
- (B) (P)→(3), (Q)→(4), (R)→(1), (S)→(4)
- (C) (P)→(3), (Q)→(5), (R)→(1), (S)→(4)
- (D) (P)→(3), (Q)→(5), (R)→(2), (S)→(4)
15. Match each entry in List-I to the correct entry in List-II and choose the correct option.
- List-I
- (P) Two distinct numbers are chosen at random from  $\{1, 2, 3, 4, 5, 6\}$ . The probability that their sum is even
- (Q) Urn A has 3 red and 2 black balls; urn B has 2 red and 3 black balls. An urn is chosen by tossing a fair coin and a ball drawn from it is red. The probability that it came from urn A
- (R) The probability that in three tosses of a fair coin the number of heads exceeds the number of tails
- (S) A and B toss a fair coin alternately, A first; the first to get a head wins. The probability that B wins
- List-II
- (1)  $1/3$ ; (2)  $2/5$ ; (3)  $1/2$ ; (4)  $3/5$ ; (5)  $2/3$
- (A) (P)→(2), (Q)→(4), (R)→(5), (S)→(1)
- (B) (P)→(2), (Q)→(5), (R)→(3), (S)→(1)
- (C) (P)→(2), (Q)→(4), (R)→(3), (S)→(1)
- (D) (P)→(4), (Q)→(2), (R)→(3), (S)→(1)
16. Match each entry in List-I to the correct entry in List-II and choose the correct option.
- List-I
- (P)  $\det A$ , where  $A$  is a  $3 \times 3$  real matrix with  $A^2 = A$  and  $A \neq I$
- (Q)  $\text{tr } A$ , where  $A$  is a  $2 \times 2$  real matrix with  $A^2 - 3A + 2I = O$ ,  $A \neq I$  and  $A \neq 2I$
- (R)  $\det(\text{adj } A)$ , where  $A$  is a  $3 \times 3$  matrix with  $\det A = -2$
- (S) The number of  $3 \times 3$  real diagonal matrices  $D$  with  $D^2 = I$
- List-II
- (1) 0; (2) 1; (3) 3; (4) 4; (5) 8
- (A) (P)→(2), (Q)→(3), (R)→(4), (S)→(5)
- (B) (P)→(1), (Q)→(2), (R)→(4), (S)→(5)
- (C) (P)→(1), (Q)→(3), (R)→(4), (S)→(5)
- (D) (P)→(1), (Q)→(3), (R)→(3), (S)→(5)

## Part II: Physics

### Physics – Section 1: One correct option (+3, –1)

17. A uniform solid sphere is released from rest on a rough plane inclined at  $30^\circ$  to the horizontal. The minimum coefficient of static friction for which it rolls without slipping is:
- (A)  $1/(3\sqrt{3})$  (B)  $1/(2\sqrt{3})$
- (C)  $5/(7\sqrt{3})$  (D)  $2/(7\sqrt{3})$

18. An air-filled parallel-plate capacitor with plate separation  $d$  is charged to a potential difference  $V_0$  and then disconnected from the battery. A dielectric slab of dielectric constant 3, thickness  $d/2$  and the same area as the plates is now inserted between the plates. The new potential difference between the plates is:
- (A)  $V_0/2$  (B)  $3V_0/4$   
(C)  $V_0/3$  (D)  $2V_0/3$
19. Light of wavelength 300 nm falling on a metal surface gives a stopping potential of 2.0 V. If light of wavelength 200 nm is used on the same surface, the stopping potential will be about (take  $hc = 1240$  eV nm):
- (A) 4.07 V (B) 6.20 V  
(C) 3.00 V (D) 2.07 V
20. A string of length 1.5 m and linear mass density 5 g/m is fixed at both ends. Two successive resonant frequencies of the string are 420 Hz and 490 Hz. The tension in the string is:
- (A) 220.5 N (B) 441 N  
(C) 110.25 N (D) 55.1 N

### Physics – Section 2: One or more correct options (+4, partial, –1)

21. One mole of a monatomic ideal gas at pressure  $P_0$ , volume  $V_0$  and temperature  $T_0$  expands to volume  $2V_0$  in a quasi-static process in which  $PV^2$  remains constant. Which of the following statements is/are correct? (One or more options may be correct.)
- (A) The final temperature of the gas is  $T_0/2$ .  
(B) The work done by the gas is  $P_0V_0/2$ .  
(C) The gas absorbs heat during the process.  
(D) The molar heat capacity of the gas in this process is  $R/2$ .
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22. A conducting rod of mass  $m$  and length  $l$  slides without friction on two long horizontal parallel rails joined at one end by a resistor  $R$ , in a uniform vertical magnetic field  $B$ . Ignore the resistance of the rod and the rails and the self-inductance of the circuit. An external force keeps the rod moving at constant speed  $v_0$  perpendicular to its length; at  $t = 0$  the force is removed. Which of the following statements is/are correct? (One or more options may be correct.)
- (A) While the rod moves at constant speed  $v_0$ , the external agent supplies power  $B^2l^2v_0^2/(2R)$ .  
(B) While the rod moves at constant speed  $v_0$ , the current in the circuit is  $Blv_0/R$ .  
(C) After the force is removed, the rod comes to rest in a finite time.  
(D) After the force is removed, the rod travels a total distance  $mv_0R/(B^2l^2)$ .
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23. A thin convex lens made of glass of refractive index 1.5 has a focal length of 20 cm in air. An object is placed 30 cm from it on its principal axis. Which of the following statements is/are correct? (One or more options may be correct.)
- (A) The image is real, inverted and twice the size of the object.
- (B) If the object is moved 10 cm towards the lens, the image forms at infinity.
- (C) If the lower half of the lens is covered with black paper, a complete image is still formed, but it is less bright.
- (D) If the lens and object are immersed in water of refractive index  $4/3$ , the focal length of the lens becomes 80 cm.

24. A satellite of mass  $m$  moves in a circular orbit of radius  $2R$  around the Earth (mass  $M$ , radius  $R$ ,  $g = GM/R^2$  at the surface). Ignore the Earth's rotation and air drag. Which of the following statements is/are correct? (One or more options may be correct.)
- (A) The period of the satellite is  $2\pi\sqrt{(2R/g)}$ .
- (B) The orbital speed of the satellite is  $\sqrt{(gR/2)}$ .
- (C) The escape speed from the orbit is  $\sqrt{2}$  times the orbital speed.
- (D) The minimum energy needed to shift the satellite to a circular orbit of radius  $3R$  is  $GMm/(12R)$ .

### Physics – Section 3: Numerical value (+4, 0)

25. A block of mass 2 kg rests on a smooth horizontal floor, attached to a fixed wall by a light horizontal spring of spring constant 800 N/m. A lump of putty of mass 0.5 kg moving at 10 m/s along the spring's axis strikes the block and sticks to it. The amplitude of the resulting oscillation, in cm, is \_\_\_\_.

26. An ideal 12 V battery is connected in series with a  $4\ \Omega$  resistor and a  $2\ \Omega$  resistor. A  $5\ \mu\text{F}$  capacitor is connected across the  $2\ \Omega$  resistor. The energy stored in the capacitor in the steady state, in  $\mu\text{J}$ , is \_\_\_\_.

27. Two radioactive samples X and Y have half-lives of 1 hour and 2 hours respectively, and they have equal activities at  $t = 0$ . The ratio of the activity of Y to that of X at  $t = 4$  hours is \_\_\_\_.

28. A large open tank standing on level ground holds water to a depth of 5 m. A small hole is made in its vertical side 1.8 m below the free surface. Taking  $g = 10\ \text{m/s}^2$ , the horizontal distance from the tank wall at which the water jet strikes the ground, in m, is \_\_\_\_.

## Physics – Section 4: Matching List Sets (+4, –1)

29. Match each physical quantity in List-I with its dimensional formula in List-II and choose the correct option. (h: Planck's constant, e: electronic charge, L: inductance, R: resistance,  $\epsilon_0$ : permittivity of free space,  $\mu_0$ : permeability of free space, E: electric field)

List-I

(P)  $h/e$

(Q)  $L/R$

(R)  $\epsilon_0 E^2$

(S)  $1/\sqrt{(\mu_0 \epsilon_0)}$

List-II

(1)  $[T]$ ; (2)  $[L T^{-1}]$ ; (3)  $[M L^{-1} T^{-2}]$ ; (4)  $[M L^2 T^{-2} A^{-1}]$ ; (5)  $[M L^2 T^{-3} A^{-1}]$

(A) (P)→(4), (Q)→(1), (R)→(2), (S)→(3)

(B) (P)→(4), (Q)→(1), (R)→(3), (S)→(2)

(C) (P)→(5), (Q)→(1), (R)→(3), (S)→(2)

(D) (P)→(4), (Q)→(3), (R)→(1), (S)→(2)

30. A series LCR circuit with  $R = 10 \Omega$ , inductive reactance  $X_L = 20 \Omega$  and capacitive reactance  $X_C = 10 \Omega$  is connected to an AC source of rms voltage 100 V. Match each quantity in List-I with its value in List-II (SI units) and choose the correct option.

List-I

(P) Impedance of the circuit

(Q) rms current

(R) Average power drawn from the source

(S) rms voltage across the inductor

List-II

(1) 500; (2)  $100\sqrt{2}$ ; (3)  $10\sqrt{2}$ ; (4) 1000; (5)  $5\sqrt{2}$

(A) (P)→(5), (Q)→(3), (R)→(1), (S)→(2)

(B) (P)→(3), (Q)→(5), (R)→(4), (S)→(2)

(C) (P)→(3), (Q)→(4), (R)→(1), (S)→(2)

(D) (P)→(3), (Q)→(5), (R)→(1), (S)→(2)

31. For an electron in the n-th Bohr orbit of a hydrogen atom, match each quantity in List-I with the way it depends on n in List-II and choose the correct option.

List-I

(P) Radius of the orbit

(Q) Time period of revolution

(R) Kinetic energy of the electron

(S) Magnetic field at the nucleus due to the orbiting electron

List-II

(1) varies as  $n^{-5}$ ; (2) varies as  $n^{-2}$ ; (3) varies as  $n^2$ ; (4) varies as  $n^3$ ; (5) varies as  $n^{-1}$

(A) (P)→(3), (Q)→(4), (R)→(1), (S)→(2)

(B) (P)→(4), (Q)→(3), (R)→(2), (S)→(1)

(C) (P)→(3), (Q)→(4), (R)→(2), (S)→(1)

(D) (P)→(3), (Q)→(4), (R)→(5), (S)→(1)

32. Match each rigid body and axis in List-I with its moment of inertia in List-II and choose the correct option. (M: mass, L: length of the rod, R: radius)

List-I

(P) Thin uniform rod, about an axis through one end perpendicular to the rod

(Q) Uniform solid sphere, about a tangent

(R) Thin uniform ring, about a diameter

(S) Thin uniform disc, about a tangent lying in its own plane

List-II

(1)  $MR^2/2$ ; (2)  $5MR^2/4$ ; (3)  $7MR^2/5$ ; (4)  $3MR^2/2$ ; (5)  $ML^2/3$

(A) (P)→(5), (Q)→(1), (R)→(3), (S)→(2)

(B) (P)→(3), (Q)→(5), (R)→(1), (S)→(2)

(C) (P)→(5), (Q)→(3), (R)→(1), (S)→(4)

(D) (P)→(5), (Q)→(3), (R)→(1), (S)→(2)

## Part III: Chemistry

### Chemistry – Section 1: One correct option (+3, –1)

33. At a certain temperature,  $N_2O_4(g) \rightleftharpoons 2NO_2(g)$  shows a degree of dissociation of 0.2 at a total equilibrium pressure of 1 atm. At the same temperature, the degree of dissociation will be 0.1 when the total equilibrium pressure is:
- (A) 4.125 atm (B) 2.000 atm  
(C) 4.000 atm (D) 3.960 atm
34. Which of the following shows the correct order of bond angle?
- (A)  $NH_3 > PH_3 > AsH_3$  (B)  $NF_3 > NH_3 > PH_3$   
(C)  $H_2S > H_2O > H_2Se$  (D)  $PF_3 > PCl_3 > PBr_3$
35. The correct order of basic strength of the following in aqueous solution is:
- (A)  $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$   
(B)  $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$   
(C)  $CH_3NH_2 > (CH_3)_2NH > NH_3 > (CH_3)_3N$   
(D)  $(CH_3)_2NH > (CH_3)_3N > CH_3NH_2 > NH_3$
36. The major product formed when 3-methylbut-1-ene reacts with HBr (in the absence of peroxide) is:
- (A) 2-bromo-2-methylbutane (B) 1-bromo-2-methylbutane  
(C) 2-bromo-3-methylbutane (D) 1-bromo-3-methylbutane

### Chemistry – Section 2: One or more correct options (+4, partial, –1)

37. For the cell  $Zn(s) | Zn^{2+}(aq, 1 M) || Cu^{2+}(aq, 1 M) | Cu(s)$ ,  $E^\circ_{cell} = 1.10 V$  at 298 K. Which of the following statements is/are correct? ( $F = 96500 C mol^{-1}$ ;  $2.303RT/F = 0.0591 V$ ) (One or more options may be correct.)
- (A) Electrons flow from the zinc electrode to the copper electrode through the external circuit.  
(B)  $\Delta G^\circ$  for the cell reaction is  $-212.3 kJ mol^{-1}$ .  
(C) Increasing  $[Zn^{2+}]$  while keeping  $[Cu^{2+}]$  fixed increases the cell emf.  
(D)  $\log K$  for the cell reaction is about 37.2.

38. Which of the following aldehydes undergo(es) the Cannizzaro reaction on heating with concentrated aqueous NaOH? (One or more options may be correct.)  
 (A) Benzaldehyde  
 (B) Acetaldehyde  
 (C) Methanal  
 (D) 2,2-Dimethylpropanal
39. Which of the following statements about diborane ( $B_2H_6$ ) is/are correct? (One or more options may be correct.)  
 (A) It contains two three-centre two-electron (3c-2e) B-H-B bonds.  
 (B) All six B-H bonds in it are of equal length.  
 (C) It is an electron-precise molecule.  
 (D) The two boron atoms and the four terminal hydrogen atoms lie in one plane.
40. Consider 0.1 molal aqueous solutions of glucose, urea, NaCl and  $K_2SO_4$  at the same temperature. Assume ideal behaviour and complete dissociation of the salts. Which of the following statements is/are correct? (One or more options may be correct.)  
 (A) The vapour pressure of the NaCl solution is higher than that of the glucose solution.  
 (B) The  $K_2SO_4$  solution has the lowest freezing point.  
 (C) The glucose and urea solutions have the same elevation of boiling point.  
 (D) The osmotic pressure of the NaCl solution is about twice that of the glucose solution.

### Chemistry – Section 3: Numerical value (+4, 0)

41. The total number of stereoisomers possible for hepta-2,5-dien-4-ol,  $CH_3-CH=CH-CH(OH)-CH=CH-CH_3$ , is \_\_\_\_.
42. The gas-phase first-order decomposition  $A(g) \rightarrow 2B(g) + C(g)$  is carried out in a closed vessel of fixed volume at constant temperature, starting with pure A at 200 mm Hg. The total pressure after 20 minutes is 400 mm Hg. The total pressure after 40 minutes, in mm Hg, is \_\_\_\_.
43. Among the following species, the number having square planar geometry is \_\_\_\_.  
 $XeF_4$ ,  $SF_4$ ,  $[Ni(CN)_4]^{2-}$ ,  $[NiCl_4]^{2-}$ ,  $ICl_4^-$ ,  $XeO_4$ ,  $[PtCl_4]^{2-}$ ,  $BrF_4^-$ ,  $CCl_4$ ,  $[Zn(NH_3)_4]^{2+}$

44. A metal of molar mass  $64 \text{ g mol}^{-1}$  crystallises in a face-centred cubic lattice. Its atomic radius is  $100\sqrt{2}$  pm. Taking  $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$ , the density of the metal, in  $\text{g cm}^{-3}$ , is \_\_\_\_.

#### Chemistry – Section 4: Matching List Sets (+4, –1)

45. Match each named reaction in List-I with the reagent(s) it uses in List-II and choose the correct option.

List-I

- (P) Etard reaction
- (Q) Gattermann–Koch reaction
- (R) Rosenmund reduction
- (S) Stephen reaction

List-II

- (1)  $\text{H}_2$ , Pd– $\text{BaSO}_4$
  - (2)  $\text{SnCl}_2/\text{HCl}$ , then  $\text{H}_3\text{O}^+$
  - (3)  $\text{CrO}_2\text{Cl}_2$  in  $\text{CS}_2$ , then  $\text{H}_3\text{O}^+$
  - (4)  $\text{CO}$ ,  $\text{HCl}$ , anhydrous  $\text{AlCl}_3/\text{CuCl}$
  - (5)  $\text{Zn-Hg}$ , concentrated  $\text{HCl}$
- (A) (P)→(4), (Q)→(3), (R)→(1), (S)→(2)  
(B) (P)→(3), (Q)→(2), (R)→(1), (S)→(4)  
(C) (P)→(3), (Q)→(4), (R)→(1), (S)→(2)  
(D) (P)→(3), (Q)→(4), (R)→(5), (S)→(2)

46. Match each species in List-I with its bond order (from molecular orbital theory) in List-II and choose the correct option.

List-I

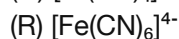
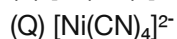
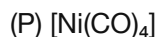
- (P)  $\text{O}_2^{2-}$
- (Q)  $\text{O}_2^-$
- (R)  $\text{N}_2^+$
- (S)  $\text{C}_2^{2-}$

List-II

- (1) 2.5; (2) 1; (3) 3; (4) 2; (5) 1.5
- (A) (P)→(2), (Q)→(1), (R)→(5), (S)→(3)  
(B) (P)→(2), (Q)→(5), (R)→(1), (S)→(3)  
(C) (P)→(2), (Q)→(5), (R)→(1), (S)→(4)  
(D) (P)→(5), (Q)→(2), (R)→(1), (S)→(3)

47. Match each complex in List-I with its hybridisation and magnetic behaviour in List-II and choose the correct option.

List-I



List-II

(1)  $\text{dsp}^2$ , diamagnetic

(2)  $\text{sp}^3\text{d}^2$ , five unpaired electrons

(3)  $\text{sp}^3$ , diamagnetic

(4)  $\text{sp}^3$ , two unpaired electrons

(5)  $\text{d}^2\text{sp}^3$ , diamagnetic

(A) (P)→(3), (Q)→(5), (R)→(4), (S)→(2)

(B) (P)→(3), (Q)→(1), (R)→(5), (S)→(2)

(C) (P)→(4), (Q)→(1), (R)→(5), (S)→(2)

(D) (P)→(3), (Q)→(1), (R)→(2), (S)→(5)

48. Match each reaction in List-I with its major organic product in List-II and choose the correct option.

List-I

(P) Propanone +  $\text{CH}_3\text{MgBr}$  in dry ether, then  $\text{H}_3\text{O}^+$

(Q) Ethanal +  $\text{HCN}$ , then hydrolysis with dilute acid on heating

(R) Benzamide +  $\text{Br}_2$  + aqueous  $\text{NaOH}$

(S) Phenol +  $\text{CHCl}_3$  + aqueous  $\text{NaOH}$ , then  $\text{H}_3\text{O}^+$

List-II

(1) 2-Hydroxybenzaldehyde

(2) Aniline

(3) 2-Methylpropan-2-ol

(4) 2-Hydroxypropanoic acid

(5) Benzoic acid

(A) (P)→(4), (Q)→(3), (R)→(2), (S)→(1)

(B) (P)→(3), (Q)→(4), (R)→(5), (S)→(1)

(C) (P)→(3), (Q)→(2), (R)→(4), (S)→(1)

(D) (P)→(3), (Q)→(4), (R)→(2), (S)→(1)

## Answer Key

|    |       |    |     |    |         |    |       |    |       |    |       |    |       |    |       |    |     |    |       |
|----|-------|----|-----|----|---------|----|-------|----|-------|----|-------|----|-------|----|-------|----|-----|----|-------|
| 1  | B     | 2  | B   | 3  | C       | 4  | D     | 5  | B,C,D | 6  | A,B,C | 7  | A,C,D | 8  | A,C   | 9  | 26  | 10 | 1.85  |
| 11 | 2     | 12 | 31  | 13 | A       | 14 | C     | 15 | C     | 16 | C     | 17 | D     | 18 | D     | 19 | A   | 20 | A     |
| 21 | A,B,D | 22 | B,D | 23 | A,B,C,D | 24 | B,C,D | 25 | 11.18 | 26 | 40    | 27 | 4     | 28 | 4.8   | 29 | B   | 30 | D     |
| 31 | C     | 32 | D   | 33 | A       | 34 | A     | 35 | B     | 36 | A     | 37 | A,B,D | 38 | A,C,D | 39 | A,D | 40 | B,C,D |
| 41 | 4     | 42 | 500 | 43 | 5       | 44 | 6.64  | 45 | C     | 46 | B     | 47 | B     | 48 | D     |    |     |    |       |

## Solutions

### Mathematics – Section 1: One correct option (+3, –1)

1. (B) Let  $c = 3 + 4i$ , so  $z = c + u$  with  $|u| = 2$ , and  $6 + 8i = 2c$ . Then  $|z|^2 + |z - 2c|^2 = |c + u|^2 + |c - u|^2 = 2|c|^2 + 2|u|^2 = 2(25) + 2(4) = 58$  for every  $z$  on the circle.
2. (B)  $Q(x) = xP(x) - 1$  has degree 4 and roots 1, 2, 3, 4, so  $Q(x) = c(x - 1)(x - 2)(x - 3)(x - 4)$ .  $Q(0) = -1$  gives  $24c = -1$ ,  $c = -1/24$ . Then  $Q(5) = -24/24 = -1$ , so  $5P(5) - 1 = -1$  and  $P(5) = 0$ .
3. (C)  $P(\text{first six on roll } k) = (5/6)^{k-1}(1/6)$ . Summing over  $k = 2, 4, 6, \dots$ :  $(1/6)(5/6)/(1 - 25/36) = (5/36)/(11/36) = 5/11$ .
4. (D)  $(1 + x)^{1/x} = e^{(\ln(1 + x)/x)} = e^{(1 - x/2 + x^2/3 - \dots)} = e(1 - x/2 + O(x^2))$ . So  $[(1 + x)^{1/x} - e]/x \rightarrow -e/2$ .

### Mathematics – Section 2: One or more correct options (+4, partial, –1)

5. (B,C,D) Correct options: (B), (C), (D).  $f(-2) = -1$ ,  $f(-1) = 3$ ,  $f(0) = 1$ ,  $f(1) = -1$ ,  $f(2) = 3$ , so all three roots are real (one each in  $(-2, -1)$ ,  $(0, 1)$ ,  $(1, 2)$ );  $f$  is decreasing on  $(-1, 1)$ , so exactly one root lies in  $(0, 1)$ . The product of the roots is  $-1$ , not 1, so (A) is false. Put  $x = 2\cos \theta$ :  $8\cos^3 \theta - 6\cos \theta + 1 = 2\cos 3\theta + 1 = 0$ , i.e.  $\cos 3\theta = -1/2$ , which holds for  $\theta = 2\pi/9$ , so (C) is true. Sum of roots = 0 and sum of products in pairs =  $-3$ , so the sum of squares =  $0 - 2(-3) = 6$ .
6. (A,B,C) Correct options: (A), (B), (C).  $d_1 \times d_2 = (2, 3, 4) \times (3, 4, 5) = (-1, 2, -1)$ , so the lines are not parallel. With  $a = (1, 2, 3)$ ,  $b = (2, 4, 5)$ :  $(b - a) \cdot (d_1 \times d_2) = (1, 2, 2) \cdot (-1, 2, -1) = 1 \neq 0$ , so the lines do not meet: they are skew, and the shortest distance is  $|1|/\sqrt{6} = 1/\sqrt{6}$ . The plane through  $(1, 2, 3)$  with normal  $(1, -2, 1)$  is  $x - 2y + z = 1 - 4 + 3 = 0$ . The origin lies on this plane, so its distance is 0 and (D) is false.
7. (A,C,D) Correct options: (A), (C), (D). Integrating  $\sin^n x \cdot \sin x$  by parts gives the reduction formula (A). Then  $I_5 = (4/5)(2/3)I_1 = 8/15$ , so (B) is false. Using (A),  $n \cdot I_n \cdot I_{n-1} = (n - 1) \cdot I_{n-1} \cdot I_{n-2}$ , so the product is constant and equals  $1 \cdot I_1 \cdot I_0 = \pi/2$ . Since  $0 \leq \sin x \leq 1$ ,  $I_{n+1} \leq I_n \leq I_{n-1}$ , so  $1 \leq I_n/I_{n+1} \leq I_{n-1}/I_{n+1} = (n + 1)/n \rightarrow 1$ , which proves (D).
8. (A,C) Correct options: (A), (C).  $a = 3$ ,  $b^2 = 5$ ,  $e = \sqrt{1 - 5/9} = 2/3$ , foci  $(\pm 2, 0)$ ;  $(2, 5/3)$  is an end of a latus rectum since  $b^2/a = 5/3$ . The tangent there is  $2x/9 + y/3 = 1$ , i.e.  $2x + 3y = 9$ , which meets the  $x$ -axis at  $(9/2, 0)$ , on the directrix  $x = a/e$ , not on the circle of radius 3, so (B) is false. By symmetry the four tangents form a rhombus with vertices  $(\pm 9/2, 0)$ ,  $(0, \pm 3)$ : area =  $(9 \times 6)/2 = 27$ . The sum of focal distances is  $2a = 6$ , so (D) is false.

### Mathematics – Section 3: Numerical value (+4, 0)

9. (26) Answer: 26. Such an  $f$  is a permutation made only of fixed points and 2-cycles. Identity: 1; exactly one 2-cycle:  ${}^5C_2 = 10$ ; exactly two 2-cycles:  $({}^5C_2 \times {}^3C_2)/2 = 15$ . Total  $1 + 10 + 15 = 26$ .
10. (1.85) Answer: 1.85.  $[x^2] = 0$  on  $[0, 1)$ , 1 on  $[1, \sqrt{2})$ , 2 on  $[\sqrt{2}, \sqrt{3})$ , 3 on  $[\sqrt{3}, 2)$ . Integral =  $(\sqrt{2} - 1) + 2(\sqrt{3} - \sqrt{2}) + 3(2 - \sqrt{3}) = 5 - \sqrt{2} - \sqrt{3} = 5 - 1.4142 - 1.7321 = 1.8537 \approx 1.85$ .
11. (2) Answer: 2. Let  $\eta = \omega + \omega^2 + \omega^4$ ; its conjugate is  $\bar{\eta} = \omega^6 + \omega^5 + \omega^3$ . Then  $\eta + \bar{\eta} = \omega + \omega^2 + \dots + \omega^6 = -1$ , and multiplying out,  $\eta\bar{\eta} = 3 + (\omega + \omega^2 + \dots + \omega^6) = 3 - 1 = 2$ . So  $|1 + \eta|^2 = (1 + \eta)(1 + \bar{\eta}) = 1 + (\eta + \bar{\eta}) + \eta\bar{\eta} = 1 - 1 + 2 = 2$ .
12. (31) Answer: 31. For  $[a, b]$ ,  $[c, d]$  we need  $ad = bc$ . A product  $xy$  with  $x, y \in \{0, 1, 2\}$  equals 0 in 5 ways, 1 in 1 way, 2 in 2 ways and 4 in 1 way. So the count is  $5^2 + 1^2 + 2^2 + 1^2 = 25 + 1 + 4 + 1 = 31$ .

### Mathematics – Section 4: Matching List Sets (+4, –1)

13. (A) (P)  $(1 - \cos 2x)/x^2 = 2 \sin^2 x/x^2 \rightarrow 2$ , so (3). (Q)  $|x^2 - 1|$  has corners at  $x = \pm 1$  and  $|x|$  at  $x = 0$ , and no two corners cancel, so 3 points: (4). (R) The substitution  $x \rightarrow \pi/2 - x$  changes the integrand into its negative, so the integral is 0: (1). (S)  $2^3 = 8 \equiv 1 \pmod{7}$  and  $2027 = 3 \times 675 + 2$ , so  $2^{2027} \equiv 2^2 = 4 \pmod{7}$ : (5).

- 14. (C)** (P) Centre  $(2, -3)$ ,  $r^2 = 4 + 9 + 12 = 25$ ,  $r = 5$ : (3). (Q) A focal chord at angle  $\theta$  has length  $4a \operatorname{cosec}^2 \theta = 4(1)(2) = 8$ : (5). (R) Focus  $(5, 0)$ , asymptote  $3x - 4y = 0$ : distance  $= 15/5 = 3$  (it always equals  $b$ ): (1). (S) Subtracting the equations gives  $8x - 7 = 25$ ,  $x = 4$ , so  $y^2 = 9$  and the chord joins  $(4, \pm 3)$ : length 6: (4).
- 15. (C)** (P) Both even or both odd:  $({}^3C_2 + {}^3C_2)/{}^6C_2 = 6/15 = 2/5$ : (2). (Q) Bayes:  $(\frac{1}{2} \cdot \frac{3}{5})/(\frac{1}{2} \cdot \frac{3}{5} + \frac{1}{2} \cdot \frac{2}{5}) = 3/5$ : (4). (R) At least 2 heads in 3 tosses:  $4/8 = 1/2$ : (3). (S)  $P(A \text{ wins}) = (1/2)/(1 - 1/4) = 2/3$ , so  $P(B \text{ wins}) = 1/3$ : (1).
- 16. (C)** (P)  $A(A - I) = O$ ; if  $\det A \neq 0$ , multiplying by  $A^{-1}$  gives  $A = I$ , which is excluded, so  $\det A = 0$ : (1). (Q)  $A$  is not a scalar matrix, so its minimal polynomial is  $(x - 1)(x - 2)$  and its eigenvalues are 1 and 2: trace 3: (3). (R)  $\det(\operatorname{adj} A) = (\det A)^{n-1} = (-2)^2 = 4$ : (4). (S) Each diagonal entry is  $\pm 1$ :  $2^3 = 8$ : (5).

### Physics – Section 1: One correct option (+3, -1)

- 17. (D)** For rolling,  $a = g \sin \theta / (1 + I/mR^2) = (5/7)g \sin \theta$  and friction  $f = mg \sin \theta - ma = (2/7)mg \sin \theta$ . Need  $f \leq \mu mg \cos \theta$ , so  $\mu \geq (2/7) \tan 30^\circ = 2/(7\sqrt{3})$ .  $(1/(3\sqrt{3}))$  would be for a disc,  $1/(2\sqrt{3})$  for a ring.)
- 18. (D)** With the slab,  $C = \epsilon_0 A / (d - t + t/K) = \epsilon_0 A / (d/2 + d/6) = \epsilon_0 A / (2d/3) = 3C_0/2$ . The charge stays the same (battery disconnected), so  $V = Q/C = V_0/(3/2) = 2V_0/3$ .
- 19. (A)** Photon energy at 300 nm  $= 1240/300 = 4.13$  eV, so the work function  $\phi = 4.13 - 2.0 = 2.13$  eV. At 200 nm the energy is 6.20 eV, so  $eV_0 = 6.20 - 2.13 = 4.07$  eV and  $V_0 \approx 4.07$  V.
- 20. (A)** For a string fixed at both ends successive harmonics differ by the fundamental, so  $f_1 = 490 - 420 = 70$  Hz. Wave speed  $v = 2Lf_1 = 2 \times 1.5 \times 70 = 210$  m/s.  $T = \mu v^2 = 0.005 \times 210^2 = 220.5$  N.

### Physics – Section 2: One or more correct options (+4, partial, -1)

- 21. (A,B,D)** Correct options: (A), (B), (D). Final pressure  $= P_0/4$ , so  $PV = P_0V_0/2$  and  $T = T_0/2$ . For  $PV^n = \text{constant}$  with  $n = 2$ ,  $W = (P_1V_1 - P_2V_2)/(n - 1) = P_0V_0 - P_0V_0/2 = P_0V_0/2$ .  $\Delta U = (3/2)R(T_0/2 - T_0) = -(3/4)P_0V_0$ , so  $Q = \Delta U + W = -P_0V_0/4$ : heat is released, and (C) is false.  $C = C_V + R/(1 - n) = 3R/2 - R = R/2$  (check:  $Q = C \cdot \Delta T = (R/2)(-T_0/2) = -RT_0/4$ ).
- 22. (B,D)** Correct options: (B), (D). The emf is  $Blv_0$  and  $I = Blv_0/R$ . The magnetic force  $BIl = B^2l^2v_0/R$  must be balanced, so the power supplied is  $B^2l^2v_0^2/R$  (all dissipated in R), not half of it: (A) is false. After removal,  $m dv/dt = -(B^2l^2/R)v$ , so  $v = v_0 e^{-(t/\tau)}$  with  $\tau = mR/(B^2l^2)$ : the speed only tends to zero, so (C) is false. Writing  $m v dv/dx = -(B^2l^2/R)v$  gives  $dv/dx = -B^2l^2/(mR)$ , so the total distance is  $mv_0R/(B^2l^2)$ .
- 23. (A,B,C,D)** Correct options: (A), (B), (C), (D).  $1/v = 1/20 - 1/30 = 1/60$ , so  $v = +60$  cm and  $m = -60/30 = -2$ : real, inverted, twice the size. At  $u = 20$  cm the object is at the focus, so the image is at infinity. Every part of the lens forms the whole image, so covering half only cuts the light. In water,  $f_w/f_a = (1.5 - 1)/(1.5/(4/3) - 1) = 0.5/0.125 = 4$ , so  $f_w = 80$  cm.
- 24. (B,C,D)** Correct options: (B), (C), (D).  $v = \sqrt{GM/2R} = \sqrt{gR^2/2R} = \sqrt{gR/2}$ .  $T = 2\pi\sqrt{r^3/GM} = 2\pi\sqrt{(8R^3)/(gR^2)} = 2\pi\sqrt{8R/g}$ , so (A) is false. Escape speed at radius  $r$  is  $\sqrt{2GM/r} = \sqrt{2} \times \text{orbital speed}$ . Orbital energy is  $-GMm/(2r)$ :  $E(3R) - E(2R) = -GMm/(6R) + GMm/(4R) = GMm/(12R)$ .

### Physics – Section 3: Numerical value (+4, 0)

- 25. (11.18)** Answer: 11.18. Momentum conservation:  $v = (0.5 \times 10)/2.5 = 2$  m/s.  $\omega = \sqrt{k/M} = \sqrt{800/2.5} = \sqrt{320} = 17.89$  rad/s. The collision happens at the equilibrium position, so  $A = v/\omega = 2/17.89 = 0.1118$  m = 11.18 cm.
- 26. (40)** Answer: 40. In the steady state no current flows into the capacitor, so  $I = 12/(4 + 2) = 2$  A and the voltage across the  $2 \Omega$  resistor (and the capacitor) is 4 V.  $U = \frac{1}{2}CV^2 = \frac{1}{2} \times 5 \mu\text{F} \times 16 \text{ V}^2 = 40 \mu\text{J}$ .
- 27. (4)** Answer: 4. Activity falls as  $A_0(1/2)^{(t/T)^{1/2}}$  whatever the number of nuclei. After 4 h,  $A_X = A_0/2^4 = A_0/16$  and  $A_Y = A_0/2^2 = A_0/4$ , so  $A_Y/A_X = 4$ .
- 28. (4.8)** Answer: 4.8. Efflux speed  $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 1.8} = 6$  m/s (Torricelli). The hole is  $5 - 1.8 = 3.2$  m above the ground, so the fall time is  $\sqrt{2 \times 3.2/10} = 0.8$  s. Range  $= 6 \times 0.8 = 4.8$  m  $(= 2\sqrt{h(H - h)}) = 2\sqrt{(1.8 \times 3.2)}$ .

### Physics – Section 4: Matching List Sets (+4, -1)

- 29. (B)** (P)  $h/e = [M L^2 T^{-1}]/[A T] = [M L^2 T^{-2} A^{-1}]$  (the dimension of magnetic flux): (4). (Q)  $L/R$  is the time constant of an LR circuit:  $[T]$ : (1). (R)  $\epsilon_0 E^2$  is (twice) an energy density, energy per volume:  $[M L^{-1} T^{-2}]$ : (3). (S)  $1/\sqrt{(\mu_0 \epsilon_0)}$  is the speed of light:  $[L T^{-1}]$ : (2).  $[M L^2 T^{-3} A^{-1}]$  is the dimension of potential difference.
- 30. (D)** (P)  $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{100 + 100} = 10\sqrt{2} \Omega$ : (3). (Q)  $I = 100/(10\sqrt{2}) = 5\sqrt{2}$  A: (5). (R)  $P = I^2 R = 50 \times 10 = 500$  W: (1). (S)  $V_L = I X_L = 5\sqrt{2} \times 20 = 100\sqrt{2}$  V: (2).

**31. (C)**  $r_n$  varies as  $n^2$  and  $v_n$  varies as  $1/n$ . (P) (3). (Q)  $T = 2\pi r/v$  varies as  $n^2/n^{-1} = n^3$ : (4). (R)  $KE = \frac{1}{2}mv^2$  varies as  $n^{-2}$ : (2). (S) The equivalent current  $I = e/T$  varies as  $n^{-3}$ , and  $B = \mu_0 I/(2r)$  varies as  $n^{-3}/n^2 = n^{-5}$ : (1).

**32. (D)** (P)  $ML^2/12 + M(L/2)^2 = ML^2/3$ : (5). (Q)  $2MR^2/5 + MR^2 = 7MR^2/5$ : (3). (R) By the perpendicular-axis theorem,  $2I_d = MR^2$ , so  $I_d = MR^2/2$ : (1). (S) Disc about a diameter is  $MR^2/4$ , so about a parallel tangent in its plane it is  $MR^2/4 + MR^2 = 5MR^2/4$ : (2). ( $3MR^2/2$  is the disc about a tangent perpendicular to its plane.)

### Chemistry – Section 1: One correct option (+3, –1)

**33. (A)** For a dissociation at total pressure  $P$ ,  $K_p = 4\alpha^2 P/(1 - \alpha^2)$ . With  $\alpha = 0.2$ ,  $P = 1$ :  $K_p = 0.16/0.96 = 1/6$ . For  $\alpha = 0.1$ :  $0.04P/0.99 = 1/6$ , so  $P = 0.99/0.24 = 4.125$  atm.

**34. (A)** Down group 15 the central atom gets larger and less electronegative, so bond pairs move apart and the angle falls:  $NH_3$  ( $\approx 107^\circ$ )  $>$   $PH_3$  ( $\approx 94^\circ$ )  $>$   $AsH_3$  ( $\approx 92^\circ$ ).  $NF_3$  ( $\approx 102^\circ$ ) is smaller than  $NH_3$ ,  $H_2O$  ( $104.5^\circ$ ) is larger than  $H_2S$  ( $\approx 92^\circ$ ), and  $PF_3$  ( $\approx 98^\circ$ ) is smaller than  $PCl_3$  ( $\approx 100^\circ$ ).

**35. (B)** In water, basicity depends on the +I effect, H-bonded solvation of the ammonium ion and steric hindrance together.  $pK_b$ :  $(CH_3)_2NH$  3.27,  $CH_3NH_2$  3.38,  $(CH_3)_3N$  4.22,  $NH_3$  4.75. The order  $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2$  holds only in the gas phase.

**36. (A)** Markovnikov addition of  $H^+$  gives the secondary carbocation  $CH_3-C^+H-CH(CH_3)_2$ , which rearranges by a 1,2-hydride shift to the more stable tertiary cation  $CH_3CH_2-C^+(CH_3)_2$ .  $Br^-$  adds there, giving 2-bromo-2-methylbutane.

### Chemistry – Section 2: One or more correct options (+4, partial, –1)

**37. (A,B,D)** Correct options: (A), (B), (D). Zinc is the anode (oxidation), so electrons leave it through the wire.  $\Delta G^\circ = -nFE^\circ = -2 \times 96500 \times 1.10 \text{ J} = -212.3 \text{ kJ mol}^{-1}$ .  $E = E^\circ - (0.0591/2) \log([Zn^{2+}]/[Cu^{2+}])$ , so raising  $[Zn^{2+}]$  lowers the emf: (C) is false.  $\log K = nE^\circ/0.0591 = 2.20/0.0591 \approx 37.2$ .

**38. (A,C,D)** Correct options: (A), (C), (D). The Cannizzaro reaction needs an aldehyde with no  $\alpha$ -hydrogen.  $C_6H_5CHO$ ,  $HCHO$  and  $(CH_3)_3C-CHO$  have none, so each disproportionates into an alcohol and a carboxylate.  $CH_3CHO$  has three  $\alpha$ -hydrogens and undergoes aldol condensation instead.

**39. (A,D)** Correct options: (A), (D). Each boron uses roughly  $sp^3$  orbitals: two form normal  $2c-2e$  bonds to terminal H atoms and two take part in the B–H–B bridges, which are  $3c-2e$  'banana' bonds. The bridge B–H bonds ( $\approx 133$  pm) are longer than the terminal ones ( $\approx 119$  pm), so (B) is false.  $B_2H_6$  has only 12 valence electrons for 8 bonding contacts: it is electron-deficient, so (C) is false. The  $B_2H_4$  unit is planar and the two bridging H atoms lie above and below that plane.

**40. (B,C,D)** Correct options: (B), (C), (D). Colligative effects depend on  $i \times m$ : glucose and urea 0.1, NaCl 0.2,  $K_2SO_4$  0.3. More solute particles mean a lower vapour pressure, so the NaCl solution has the lower vapour pressure: (A) is false.  $K_2SO_4$  ( $i = 3$ ) shows the greatest depression of freezing point; glucose and urea ( $i = 1$ ) give the same  $\Delta T_b$ ;  $\pi = iCRT$ , so NaCl gives about twice the osmotic pressure of glucose.

### Chemistry – Section 3: Numerical value (+4, 0)

**41. (4)** Answer: 4. Each  $C=C$  can be E or Z. In the (2E,5E) and (2Z,5Z) forms, C-4 carries two identical propenyl groups, so it is not a stereocentre and each form is a single achiral compound. In the (2E,5Z) form, C-4 carries H, OH, an E-propenyl and a Z-propenyl group, so it is a chiral centre and gives a pair of enantiomers. Total  $1 + 1 + 2 = 4$ .

**42. (500)** Answer: 500. If A falls by  $x$ , the total pressure is  $(200 - x) + 2x + x = 200 + 2x$ . At 20 min,  $400 = 200 + 2x$  gives  $x = 100$ , so half of A has gone and  $t_{1/2} = 20$  min. At 40 min (two half-lives) A has fallen by 150, so  $P = 200 + 300 = 500$  mm Hg.

**43. (5)** Answer: 5. Square planar:  $XeF_4$ ,  $ICl_4^-$  and  $BrF_4^-$  (4 bond pairs + 2 lone pairs, octahedral electron geometry), and  $[Ni(CN)_4]^{2-}$  and  $[PtCl_4]^{2-}$  ( $d^8$ ,  $dsp^2$ ).  $SF_4$  is see-saw;  $[NiCl_4]^{2-}$  (weak-field ligand),  $XeO_4$ ,  $CCl_4$  and  $[Zn(NH_3)_4]^{2+}$  ( $d^{10}$ ) are tetrahedral.

**44. (6.64)** Answer: 6.64. In fcc, atoms touch along the face diagonal:  $4r = \sqrt{2}a$ , so  $a = 2\sqrt{2}r = 2\sqrt{2} \times 100/\sqrt{2} = 400$  pm =  $4.00 \times 10^{-8}$  cm, and  $a^3 = 6.4 \times 10^{-23}$  cm<sup>3</sup>. With  $Z = 4$ :  $\rho = ZM/(N_A a^3) = (4 \times 64)/(6.022 \times 10^{23} \times 6.4 \times 10^{-23}) = 256/38.54 = 6.64$  g cm<sup>-3</sup>.

## Chemistry – Section 4: Matching List Sets (+4, –1)

- 45. (C)** (P) Etard: toluene + chromyl chloride gives a chromium complex that is hydrolysed to benzaldehyde: (3). (Q) Gattermann–Koch: benzene + CO/HCl with anhydrous  $\text{AlCl}_3/\text{CuCl}$  gives benzaldehyde: (4). (R) Rosenmund: acyl chloride +  $\text{H}_2$  over Pd– $\text{BaSO}_4$  (poisoned) gives an aldehyde: (1). (S) Stephen: a nitrile is reduced by  $\text{SnCl}_2/\text{HCl}$  to an imine salt, which is hydrolysed to an aldehyde: (2). Zn–Hg/HCl is the Clemmensen reduction.
- 46. (B)** Bond order = (bonding – antibonding electrons)/2. (P)  $\text{O}_2^{2-}$  (18 electrons):  $(10 - 8)/2 = 1$ : (2). (Q)  $\text{O}_2^-$  (17):  $(10 - 7)/2 = 1.5$ : (5). (R)  $\text{N}_2^+$  (13):  $(9 - 4)/2 = 2.5$ : (1). (S)  $\text{C}_2^{2-}$  (14 electrons, isoelectronic with  $\text{N}_2$ ): 3: (3).
- 47. (B)** (P) Ni(0),  $3d^{10}$  (CO pairs up the 4s electrons):  $sp^3$ , diamagnetic: (3). (Q)  $\text{Ni}^{2+}$   $d^8$  with strong-field  $\text{CN}^-$ : square planar  $dsp^2$ , diamagnetic: (1). (R)  $\text{Fe}^{2+}$   $d^6$  with  $\text{CN}^-$ : low-spin  $t_2g^6$ , inner-orbital  $d^2sp^3$ , diamagnetic: (5). (S)  $\text{Fe}^{3+}$   $d^5$  with weak-field  $\text{F}^-$ : high spin, outer-orbital  $sp^3d^2$ , five unpaired electrons: (2). 'sp<sup>3</sup>, two unpaired' fits  $[\text{NiCl}_4]^{2-}$ .
- 48. (D)** (P)  $\text{CH}_3\text{MgBr}$  adds to the ketone to give  $(\text{CH}_3)_3\text{C}-\text{OH}$ : (3). (Q) The cyanohydrin  $\text{CH}_3\text{CH}(\text{OH})\text{CN}$  hydrolyses to lactic acid,  $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ : (4). (R) Hofmann bromamide degradation removes one carbon:  $\text{C}_6\text{H}_5\text{CONH}_2 \rightarrow \text{C}_6\text{H}_5\text{NH}_2$ : (2). (S) Reimer–Tiemann reaction puts a CHO group ortho to OH: salicylaldehyde: (1).