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Chemistry, 2017 EC, entrance exam, version 1

Grade 12 · Chemistry · 2017 E.C.

MARKING KEY — CONFIDENTIAL

Time allowed: 120 minutes | **Questions:** 76 | **Total marks:** 76

1. Which of the following atomic models is NOT expressed correctly? (1)

A. Dalton's atomic model. billiard ball model

B. Thomson's model of atom .Plum pudding model

C. ✓ **Thomson's model of atom .Planetary model**

D. Rutherford atomic model .Nuclear model

Answer: C

The planetary model, with electrons circling a central nucleus the way planets orbit the sun, came from Rutherford and was refined by Bohr. Thomson's picture had no nucleus at all: he described a ball of positive charge with electrons stuck through it, which is the plum pudding model. Pairing Thomson with the planetary model is therefore the mismatch. Option B names Thomson too, but plum pudding is exactly what he proposed, so that row is matched correctly.

2. Suppose an unknown element does NOT deflect cathode rays in an electric field but has significant mass. Based on atomic models, which subatomic particle could it be composed of, and how would this impact the element's atomic structure? (1)

A. Protons; making the nucleus positively charged

B. ✓ **Neutrons; contributing to atomic mass without charge**

C. Electrons; moving freely in orbitals

D. Positrons; leading to an unstable atom

Answer: B

Cathode rays are beams of electrons, and a charged particle placed in an electric field is pushed to one side. This particle is not deflected, so it carries no charge. It still has real mass, and the only subatomic particle that is heavy and neutral is the neutron. It adds to the mass number without changing the atomic number. Option A is tempting because protons are heavy as well, but a proton is positive and the field would deflect it.

3. A student is studying an atom with a mass number of 23 and an atomic number of 11. Based on nuclear composition, which of the following statements is correct? (1)

A. ✓ **The nucleus contains 11 protons and 12 neutrons**

B. The nucleus contains 11 neutrons and 12 protons

C. The nucleus contains only 11 protons

D. The nucleus contains 23 neutrons and 11 protons

Answer: A

The atomic number counts the protons, so this atom has 11 protons. The mass number counts protons plus neutrons together, so the neutrons are $23 - 11 = 12$. The nucleus holds 11 protons and 12 neutrons. Option D is tempting if you read 23 as the number of neutrons, but 23 is the total of both kinds of particle, not the neutrons alone.

4. A scientist shines red and blue light on a metal surface. The red light does not eject electrons, but the blue light does. What conclusion can be drawn? (1)

A. The red light has higher intensity than the red light

B. ✓ **The blue light has a higher frequency and sufficient energy**

C. The red light has more energy than the blue light

D. The photoelectric effect depends only on intensity, not frequency

> **Answer:** B
> In the photoelectric effect a single photon must carry at least the work function energy before an electron can leave the metal. Photon energy is $E = h\nu$, so it is set by frequency, not by how bright the beam is. Blue light has the higher frequency, so its photons carry enough energy while red photons do not. Option D is tempting because a brighter beam does eject more electrons, but that only happens once the frequency is already above the threshold. Below it, no amount of intensity helps.

5. The maximum kinetic energy of photoelectrons ejected from a metal when it is subjected to a radiation of frequency 3.0 × 10^15 Hz is 6.63 × 10^-19 J. The threshold frequency, ν_0 of the photoelectron of the metal is (1)

A. 1.0×10^15 Hz

B. 2.0×10^-15 Hz

C. 3.0×10^15 Hz

D. ✓ **2.0×10^15 Hz**

> **Answer:** D
> Use $h\nu = h\nu_0 + KE_{max}$. The incoming photon carries $E = 6.63 \times 10^{-34} \times 3.0 \times 10^{15} = 1.99 \times 10^{-18}$ J. Take away the kinetic energy: $h\nu_0 = 1.99 \times 10^{-18} - 6.63 \times 10^{-19} = 1.33 \times 10^{-18}$ J. Then $\nu_0 = 1.33 \times 10^{-18} \div 6.63 \times 10^{-34} = 2.0 \times 10^{15}$ Hz. Option B carries the right digits but a negative power of ten, and 2.0×10^{-15} Hz is not a frequency any light source produces.

6. Which of the following correctly explains Heisenberg's Uncertainty Principle? (1)

A. The exact position and momentum of a particle can be simultaneously determined.

B. ✓ **The more precisely the position of an electron is known, the less precisely its momentum is known.**

C. It suggests that electrons move in fixed circular orbits around the nucleus.

D. It only applies to macroscopic objects and not quantum particles.

> **Answer:** B
> Heisenberg's principle says the position and the momentum of a particle cannot both be pinned down at the same moment. The more tightly you fix where the electron is, the more its momentum is left uncertain, because $\Delta x \cdot \Delta p \geq h/4\pi$. Option A states the opposite. Option D is tempting, but the limit applies to every object. It only matters for very light particles such as electrons, where the uncertainty is large compared with the values themselves.

7. Why do ionic compounds typically have higher melting points than covalent compounds? (1)

A. Due to ionic bonds involve electron sharing.

B. ✓ **Due to ionic lattices have strong electrostatic forces.**

C. Due to covalent bonds are weaker than van der Waals forces.

D. Due to ionic compounds have lower polarity?

> **Answer:** B
> In an ionic solid every positive ion is pulled by the negative ions all around it, and this network of electrostatic attraction runs through the whole crystal. Melting means pulling that lattice apart, which needs a lot of heat. A molecular covalent substance only has to have its weak intermolecular forces broken, not its covalent bonds, so it melts far more easily. Option C is tempting, but the fair comparison is lattice attraction against van der Waals forces, and van der Waals forces are the weaker ones.

8. Using Born-Haber cycle, what is the lattice energy of NaCl, given the following data? Sublimation energy of Na = +108 kJ/mol; Ionization energy of Na = +496 kJ/mol; Bond dissociation of Cl_2 = +240 kJ/mol; Electron affinity of Cl = -349 kJ/mol; Enthalpy formation of NaCl = -411 kJ/mol. (1)

A. -750 kJ/mol
B. -880 kJ/mol
C. ✓ **-786 kJ/mol**
D. -920 kJ/mol

> **Answer:** C
> The Born-Haber cycle adds the steps that build NaCl from its elements: sublimation, ionisation, half the Cl-Cl bond energy (one chlorine atom is needed, not two), electron affinity and lattice energy. Half of 240 is 120. So $-411 = 108 + 496 + 120 - 349 + U$. The known terms add to $+375$, which leaves $U = -411 - 375 = -786$ kJ/mol. A common slip is to use the full 240 kJ/mol for the bond, which pushes the answer to about -906 kJ/mol and matches none of the options.

9. Which of the following molecules is an exception to the octet rule due to having an incomplete octet? (1)

A. CO_2
B. ✓ **$BeCl_2$**
C. NH_3
D. CH_4

> **Answer:** B
> Beryllium brings two valence electrons and forms two bonds in $BeCl_2$, so it ends up surrounded by only four electrons. That is an incomplete octet. In CO_2, NH_3 and CH_4 the central atom reaches the full eight. Option A is tempting because carbon dioxide is drawn with double bonds, but each double bond counts as four electrons and carbon still holds a complete octet.

10. Which molecular shape is expected when a central atom has three bonding pairs and one lone pair? (1)

A. Trigonal planar
B. Tetrahedral
C. ✓ **Trigonal pyramidal**
D. Trigonal bipyramidal

> **Answer:** C
> Four electron groups around a central atom spread out into a tetrahedral arrangement. When one of the four is a lone pair, only three bonded atoms can be seen, and the shape they make is a pyramid with a triangular base, as in ammonia. Option A is tempting because there are three bonds, but trigonal planar needs three electron groups and no lone pair, so all four atoms lie flat.

11. According to valence shell electron pair repulsion (VSEPR) theory, what is the molecular shape of PF_5? (1)

A. Trigonal planar
B. Tetrahedral
C. ✓ **Trigonal bipyramidal**
D. Octahedral

> **Answer:** C
> Phosphorus in PF_5 forms five bonds and keeps no lone pair. Five electron groups get as far from each other as they can by taking a trigonal bipyramidal arrangement: three fluorines in a flat triangle around the middle, one above and one below. Option D is tempting, but an octahedron needs six groups, and this molecule has five.

12. Which of the following sample routine correctly indicate the extraction of copper from its principal ore? (1)

A. Concentration of ores → Reduction → Roasting → Purification
B. ✓ **Concentration of ores → Roasting → Reduction → Purification**
C. Concentration of ores → Purification → Roasting → Reduction
D. Purification → Concentration of ores → Reduction → Roasting

> **Answer:** B
> Copper is taken mainly from copper pyrites. The crushed ore is first concentrated by froth flotation to throw away the waste rock. Roasting in air then burns off sulfur and turns the ore into the oxide. That oxide is reduced to crude copper metal, and electrolytic refining raises the purity to about 99.9%. Option A swaps roasting and reduction, but there is nothing to reduce until roasting has produced the oxide.

13. Though Graphite is a non-metal, it conducts electricity. Which of the following is correctly explaining this property? (1)

A. ✓ **Due to the presence of delocalized electrons within its structure that allow charge movement.**

B. Because it is made of ionic bonds, allowing ions to move freely.

C. Because it contains metallic bonds similar to those in metals.

D. Due to Graphite atoms are arranged randomly, which increases conductivity.

> **Answer:** A
> Each carbon in graphite is bonded to three others, so one electron per atom is left over and spreads out across the whole layer. Those delocalised electrons drift when a voltage is applied, and that flow is the current. Option C is tempting because free electrons also explain why metals conduct, but graphite is held together by covalent bonds inside its layers, not by metallic bonding.

14. Which type of intermolecular force is primarily responsible for the high boiling point of water? (1)

A. Ion-dipole interactions

B. London dispersion forces

C. ✓ **Hydrogen bonding**

D. Covalent bonding

> **Answer:** C
> Water's oxygen is strongly electronegative and carries lone pairs, so the hydrogen of one molecule is attracted to the oxygen of the next. Hydrogen bonding of this kind is much stronger than an ordinary dipole attraction, so a great deal of energy is needed before molecules can escape as vapour. That is why so small a molecule boils as high as 100 degrees Celsius. London dispersion forces in option B are present too, but on their own they would predict a boiling point far below zero.

15. Which of the following represents the correct molecular orbital electron configuration of O_2? (1)

A. ✓ **$\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2\ \sigma 2p_x^2\ (\pi 2p_y^2 = \pi 2p_z^2)\ (\pi^*2p_y^1 = \pi^*2p_z^1)$**

B. $\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2\ \sigma 2p_x^2\ \pi 2p_y^2 = \pi 2p_z^2\ \pi^*2p_y^2$

C. $\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2\ \pi 2p_y^2 = \pi 2p_z^2\ \sigma 2p_x^2\ \pi^*2p_y^2 = \pi^*2p_z^1$

D. $\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2\ \sigma 2p_x^2\ \pi 2p_y^2 = \pi 2p_z^2\ \pi^*2p_z^2$

> **Answer:** A
> Oxygen has 16 electrons in total. Filling the molecular orbitals in order gives $\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2\ \sigma 2p_x^2$, then four electrons in the two π orbitals, which leaves two electrons for the two π^* orbitals. Hund's rule puts one in each with parallel spins, and those two unpaired electrons are why liquid oxygen is pulled towards a magnet. Option D packs both electrons into one π^* orbital, which breaks Hund's rule and would wrongly make O_2 non-magnetic.

16. Why does the molecular geometry of ammonia (NH_3) have a trigonal pyramidal shape rather than being a tetrahedral shape? (1)

A. ✓ **Due to the presence of lone pair-bonding pair repulsion on nitrogen**

B. Due to the presence of hydrogen bonding in ammonia molecule.

C. Because nitrogen exhibits sp-hybridization

D. Because the hydrogen atoms are different in size

> **Answer:** A
> Nitrogen in ammonia has four electron groups: three bonds to hydrogen and one lone pair. A lone pair sits closer to the nitrogen than a bonding pair and pushes harder, so it squeezes the three N-H bonds together to about 107 degrees instead of 109.5. Only the atoms are counted when naming a shape, so what we see is a pyramid. Option C is tempting, but nitrogen here is sp^3 hybridised, and sp hybridisation would force the molecule into a straight line.

17. If a molecule has sp hybridization, what will its molecular geometry be? (1)

A. Tetrahedral
B. Trigonal planar
C. ✓ **Linear**
D. Bent

> **Answer:** C
> sp hybridisation mixes one s orbital with one p orbital and produces two hybrid orbitals. They repel each other as far as possible, so they point in opposite directions, 180 degrees apart, and the molecule is linear. $\mathrm{BeCl_2}$ and the two carbons of ethyne are the usual examples. Option B belongs to sp^2, where three hybrid orbitals sit at 120 degrees in a flat triangle.

18. If the temperature of a gas decreases while the volume remains constant, what happens to the pressure? (1)

A. Increases
B. ✓ **Decreases**
C. Stays the same
D. Doubles

> **Answer:** B
> At fixed volume the pressure comes from gas particles striking the container walls. Cooling the gas slows the particles, so they hit the walls less often and with less force, and the pressure drops. Gay-Lussac's law states this as P/T staying constant, so lowering T lowers P. Option A is tempting if you confuse this with squeezing a gas into a smaller space, but the volume here does not change.

19. A gas occupies 2 L at 300 K. If the temperature increases to 600 K at constant pressure, what will be its new volume? (1)

A. 1 L
B. 2 L
C. ✓ **4 L**
D. 6 L

> **Answer:** C
> Pressure is constant, so Charles's law applies: $V_1/T_1 = V_2/T_2$. Both temperatures are already in kelvin, so $V_2 = 2 \times 600 \div 300 = 4$ L. Option B is tempting if you assume the gas is trapped at one size, but at constant pressure the gas is free to push outward, and doubling the kelvin temperature doubles the volume.

20. Why do solids have a fixed shape? (1)

A. Their particles are far apart and move freely
B. ✓ **Their particles are tightly packed**
C. Their particles slide past each other
D. Their particles have the highest kinetic energy

> **Answer:** B
> In a solid the particles sit close together and are held in fixed positions by strong forces. They vibrate about those positions but cannot move past one another, so the piece keeps its own shape wherever you put it. Option C describes a liquid: there the particles do slide past each other, which is why a liquid takes the shape of its container.

21. What type of bond you observe in phenol? (Image placeholder) (1)

A. 5 C-H, 3 C=C, 5 C-C and 1 O-H
B. ✓ **5 C-H, 3 C=C, 3 C-C, 1 C-O and 1 O-H**
C. 5 C-H, 6 C-C, 2 C-O and 1 O-H
D. 5 C-H, 4 C=C, 2 C-C, 2 C-O and 1 O-H

> **Answer:** B
> Phenol is a benzene ring carrying an OH group. Five of the six ring carbons still hold a hydrogen, which gives 5 C-H bonds. Drawn in the Kekule form the ring alternates, so 3 C=C and 3 C-C. The sixth carbon is joined to the oxygen, giving 1 C-O, and the oxygen holds 1 O-H. That is option B. Option A counts 5 C-C and leaves out the C-O bond, but the ring has six carbon to carbon bonds in all, three of them double.

22. Which of the following statements about the three states of matter is FALSE? (1)

A. Solids have definite shape and volume

B. Liquid attain the shape of container

C. ✓ **Gases have definite shape and volume**

D. Gases can be compressed easily

> **Answer:** C
> A gas spreads out to fill whatever container it is put in, so it has neither a definite shape nor a definite volume. Statement C therefore is the false one, which is what the question asks for. Option D is tempting because it also talks about gases, but gases really are easy to compress, since there is a lot of empty space between the particles, so D is a true statement.

23. Which of the following is NOT a factor affecting rate of reaction? (1)

A. Pressure of gaseous substance

B. ✓ **Concentration of product**

C. Surface area of solid substance

D. Temperature of solid

> **Answer:** B
> Reaction rate depends on how often reactant particles meet and how hard they collide: the concentration or pressure of the reactants, the surface area of any solid, the temperature, and any catalyst present. The amount of product sitting there does not drive the forward reaction, so it is not a rate factor. Option A is tempting because pressure matters a great deal for gases, but that is the pressure of a reacting gas, which is another way of describing its concentration.

24. In the reaction X + 3Y → 2Z, how does disappearance rate of Y compare with the rate of appearance of Z? (1)

A. The rate of disappearance of Y is 1/2 the rate of appearance of Z

B. ✓ **The rate of disappearance of Y is 3/2 the rate of appearance of Z**

C. The rate of disappearance of Y is 2/3 the rate of appearance of Z

D. The rate of disappearance of Y is 1/3 the rate of appearance of Z

> **Answer:** B
> Divide each rate by its own coefficient: $-\frac{1}{3}\frac{d[Y]}{dt} = \frac{1}{2}\frac{d[Z]}{dt}$. Rearranging gives $-\frac{d[Y]}{dt} = \frac{3}{2}\frac{d[Z]}{dt}$. Three Y are used up for every two Z formed, so Y disappears faster than Z appears. Option C turns the ratio upside down, which would be right only if two Y made three Z.

25. How does catalyst generally affect the rate of a chemical reaction? (1)

A. Positive catalyst promote the rate of reaction by increasing activation energy

B. ✓ **Positive catalyst promote the rate of reaction by decreasing activation energy**

C. Inhibitor facilitate the rate of reaction with constant activation energy

D. Catalyst doesn't affect rate of reaction

> **Answer:** B
> A catalyst offers the reaction a different route with a lower activation energy. A larger share of the colliding particles then has enough energy to react, so the rate rises. The catalyst is not used up and does not change how much product is possible at equilibrium. Option A is tempting because it names the same quantity, but raising the activation energy would slow the reaction down, which is what an inhibitor does.

26. If you need to design an experiment to increase the rate of reaction between magnesium and hydrochloric acid, which combination of factors would work best? (1)

A. Use large pieces of magnesium and decrease temperature

B. ✓ **Crush magnesium block into powder and use a catalyst**

C. Reduce hydrochloric acid concentration and add a catalyst

D. Increase pressure and decrease reactant concentration

> **Answer:** B
> Powder exposes far more surface than one solid block, so acid particles meet many more magnesium atoms every second. Adding a catalyst lowers the activation energy on top of that. Both changes push the rate up. Option A is tempting because it mentions surface area, which is a real factor, but large pieces mean less exposed surface, and cooling slows the particles down as well.

27. What does Le Chatelier's Principle predict when the concentration of reactants in a system at equilibrium is increased? (1)

A. The equilibrium will shift to favor the reactants.

B. ✓ **The equilibrium will shift to favor the products.**

C. The equilibrium will not shift

D. The reaction will stop.

> **Answer:** B
> Le Chatelier's principle says a system at equilibrium answers a disturbance by working against it. Adding reactant makes the forward reaction run faster than the reverse for a while, so the extra reactant is used up and more product forms, until the ratio settles again. Option A is tempting because it names the reactant side, but shifting towards the reactants would pile up even more of what is already in excess.

28. The value of the equilibrium constant, Kc for the reaction given: A + 2B ⇌ 2C is 10. What is the value of the equilibrium constant for the reaction: 6C ⇌ 3A + 6B? (1)

A. 0.010

B. 1000

C. ✓ **0.001**

D. 10

> **Answer:** C
> The target equation is the original one reversed and then multiplied by 3. Reversing an equation inverts its constant: $1/K = 1/10$. Multiplying an equation by 3 raises the constant to the third power: $(1/10)^3 = 1 \times 10^{-3}$, which is 0.001. Option A comes from reversing and then doubling, but the target shows 6C and 3A, which is three times $2C$ and A.

29. Which elements are commonly found in the alloy of bronze? (1)

A. ✓ **Copper and tin**

B. Iron and carbon

C. Aluminum and zinc

D. Nickel and chromium

> **Answer:** A
> Bronze is an alloy of copper with tin, usually around 88% copper. The tin makes the copper harder and easier to cast, which is why bronze served for tools, weapons and bells long before iron working spread. Option B is tempting because iron with carbon is an equally familiar alloy, but that combination is steel.

30. In general, melting point of fat is _____ and melting point of oil is _____ (1)

A. Higher, higher
B. Lower, lower
C. ✓ **Higher, lower**
D. Lower, higher

> **Answer:** C
> Fats are built mostly from saturated chains. Straight chains stack closely together, the attractions between them add up, and the melting point sits above room temperature, so a fat is solid. Oils are unsaturated: the double bonds put kinks in the chain, the molecules cannot pack as tightly, the attractions are weaker and the melting point is lower, so an oil stays liquid. Option D reverses the two, but the substance that is solid at room temperature has to be the one that melts higher.

31. Given the general structure of organic compounds: R-CH_2-CH_2CH_2 OH ... monohydric alcohol; R-CH_2-CH_2COOH ... Carboxylic acid; R-CH_2CH_2CHO ... Aldehyde. Then which general formula derived for monohydric alcohol, carboxylic acid and aldehyde respectively? (1)

A. ✓ **$C_nH_{2n+1}(OH)$, $C_nH_{2n}(O)_2$, $C_nH_{2n-2}(O)$**
B. $C_nH_{2n}(OH)$, $C_nH_{2n}(O)$, $C_nH_{2n}(O)$
C. $C_nH_{2n}(OH)$, $C_nH_{2n+1}(O)$, $C_nH_{2n}(O)$
D. $C_nH_{2n}(OH)$, $C_nH_{2n}(O)$, $C_nH_{2n}(O)_2$

> **Answer:** A
> Work out each general formula from the structures given. A monohydric alcohol is a saturated alkyl group plus one OH, which comes to $\mathrm{C_nH_{2n+1}OH}$. A carboxylic acid carries COOH, and counting every atom gives $\mathrm{C_nH_{2n}O_2}$. Only option A gets both of these right. The other options write the alcohol as $\mathrm{C_nH_{2n}(OH)}$, which is one hydrogen short for a saturated chain, so they fail on the first formula already. The aldehyde term printed in option A carries a typing slip, since an aldehyde is $\mathrm{C_nH_{2n}O}$, so it is the alcohol and the acid that decide this question.

32. Why carboxylic acids are more acidic than alcohols both of them have a hydrogen atom attached to an oxygen atom (—O—H)? Because: (1)

A. ✓ **Carboxylic acids can release proton easier than alcohols.**
B. The intermolecular force of carboxylic acid is stronger than that of alcohol
C. The boiling point of carboxylic acid is higher than that of alcohol
D. The surface area of carboxylic acid is greater than that of alcohol

> **Answer:** A
> When a carboxylic acid loses its proton, the negative charge left behind is shared evenly over both oxygen atoms of the COO group. Spreading the charge makes the ion stable, so the proton leaves readily and the acid is measurably acidic. An alcohol has nowhere to spread the charge, so its alkoxide is unstable and the alcohol holds its proton tightly. Option C is tempting because carboxylic acids do boil higher, but boiling point measures the forces holding whole molecules together, not how easily a proton is released.

33. In which of the following compounds, IUPAC name, common name and its structure is NOT correctly matched? (1)

A. Ethanedioic acid - Oxalic acid - HO_2C-CO_2H
B. Propanedioic acid - Malonic acid - $HO_2CCH_2CO_2H$
C. Butanedioic acid - Succinic acid - $HO_2C(CH_2)_2CO_2H$
D. ✓ **Pentanedioic acid - Glutaric acid - $HO_2CCH_2CO_2H$**

> **Answer:** D
> Pentanedioic acid has five carbons in the chain: one in each COOH group and three between them, so glutaric acid is $\mathrm{HO_2C(CH_2)_3CO_2H}$. The formula printed in option D has only one $\mathrm{CH_2}$, a three carbon chain, which is propanedioic acid instead. That row is the mismatch. Option B is tempting because malonic acid is a less familiar name, but its row is right: propanedioic acid is malonic acid, and its formula is $\mathrm{HO_2CCH_2CO_2H}$.

34. Esters are reduced to primary alcohols by special reducing agents. What is the most appropriate reagent used to do this reduction? (1)

A. ✓ **$LiAlH_4/H^+$**
B. V_2O_5
C. $KMnO_4$
D. Pt/Pd

> **Answer:** A
> Lithium aluminium hydride is a powerful hydride donor. It attacks the ester carbonyl and delivers hydride twice, so the ester is broken apart and reduced all the way down to a primary alcohol once the mixture is worked up with acid. Option D is tempting because platinum and palladium with hydrogen reduce many groups, but they leave an ester carbonyl untouched under normal conditions.

35. Which of the following are the correct postulates of Dalton atomic theory that are inconsistent with modern atomic theory? (1)

A. All elements are made up of small particles called atoms
B. Compounds are formed when atoms of more than one element combine
C. ✓ **Any matter is composed from indivisible atoms**
D. Atoms of the same elements have identical chemical properties.

> **Answer:** C
> Dalton stated that atoms cannot be divided. Later work found electrons, protons and neutrons inside the atom, so that postulate does not survive in modern atomic theory. The other three statements still hold in the form Dalton gave them. Option D is tempting because atoms of one element can differ in mass as isotopes, but their chemical properties are still the same, since chemistry is decided by the electrons.

36. What is the main product when benzene is treated with a mixture of concentrated nitric acid and sulfuric acid? (1)

A. ✓ **Nitrobenzene**
B. Benzaldehyde
C. Phenol
D. Toluene

> **Answer:** A
> Concentrated nitric acid mixed with concentrated sulfuric acid generates the nitronium ion, NO_2^+. Benzene attacks it, and after a proton is lost the ring gets its aromatic system back with an NO_2 group in place of one hydrogen. The product is nitrobenzene. Option C is tempting because both acids contain oxygen, but turning benzene into phenol takes a completely different route, not nitration.

37. What is the period and group of the element with atomic number 13? (1)

A. Period 2, Group IIA
B. Period 3, Group IIA
C. ✓ **Period 3, Group IIIA**
D. Period 4, Group IIA

> **Answer:** C
> Atomic number 13 is aluminium, and its configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$. The highest occupied shell is $n = 3$, so the element sits in period 3. It has three valence electrons, $3s^2 3p^1$, which places it in group IIIA. Option B is tempting if you count only the two $3s$ electrons, but the single $3p$ electron is a valence electron as well.

38. Which of the following is TRUE about the periodic properties of elements? (1)

A. ✓ **Alkali metals lose electrons more easily due to lower ionization energy**

B. Halogens gain electrons less readily due to higher electron affinity

C. Both alkali metals and halogens are more readily to lose electron at arbitrary condition

D. Alkali metals gain electrons more readily than halogens.

> **Answer:** A
> An alkali metal has one electron alone in a new outer shell, well shielded from the nucleus by the filled shells underneath, so pulling it away needs very little energy. That low ionisation energy is exactly why alkali metals lose an electron so readily and form $+1$ ions. Option B is tempting because halogens really do have high electron affinity, but a high electron affinity means they gain electrons more readily, so the statement contradicts itself.

39. Which of the following statements is TRUE about polar covalent molecules? (1)

A. They have equal sharing of electrons

B. They always involve symmetrical geometry

C. They dissolve easily in benzene.

D. ✓ **They have unequal sharing of electrons.**

> **Answer:** D
> When two bonded atoms have different electronegativities, the shared pair is pulled towards the more electronegative atom. The sharing is unequal, so one end of the bond becomes slightly negative and the other slightly positive, which is what polar means. Option A is tempting because sharing is the definition of a covalent bond, but equal sharing describes a nonpolar bond such as the one in $\mathrm{Cl_2}$.

40. A Grade 12 student claims that hydrogen bonding and dipole-dipole forces are equally strong. How would you assess this statement? (1)

A. The student is correct because both forces occur between polar molecules.

B. ✓ **The student is incorrect because dipole-dipole forces are weaker than hydrogen bonding.**

C. The student is incorrect because dipole-dipole interactions only exist in ionic compounds.

D. The student is correct because both forces require permanent dipoles.

> **Answer:** B
> Hydrogen bonding is the strong special case that appears when hydrogen is bonded to nitrogen, oxygen or fluorine. Ordinary dipole to dipole attraction between polar molecules is much weaker. That difference is why water boils at 100 degrees Celsius while hydrogen sulfide, a molecule of similar size, boils at about minus 60. So the student is wrong. Option A is tempting because both forces do act between polar molecules, but sharing a setting does not make two forces equal in strength.

41. Which of the following is the best example of the Law of Conservation of Mass? (1)

A. ✓ **10 g of hydrogen reacts with 80 g of oxygen to form 90 g of water.**

B. 10 g of hydrogen reacts with 40 g of oxygen to form 30 g of water.

C. 10 g of hydrogen reacts with 10 g of oxygen to form 5 g of water.

D. 10 g of hydrogen reacts with 5 g of oxygen to form 20 g of water.

> **Answer:** A
> The law of conservation of mass says the total mass before a reaction equals the total mass after it, because atoms are only rearranged. In option A, $10 + 80 = 90$ g, so the books balance, and the ratio is the real one for water as well: 5 mol of $\mathrm{H_2}$ reacting with 2.5 mol of $\mathrm{O_2}$. Option B is tempting if you imagine the reaction stopping part way, but even then the products plus any leftover reactant must still weigh 50 g, and 30 g leaves 20 g unaccounted for.

42. Which of the following is TRUE about conjugated acid-base pair? (1)

A. The stronger the acid, the weaker its conjugate acid.

B. The stronger the acid, the stronger its conjugate base.

C. ✓ **Conjugated acid has one more hydrogen than its base.**

D. Conjugated base has one fewer negative charge than its acid.

> **Answer:** C
> A conjugate acid and its base differ by exactly one proton and by one unit of charge. The acid is the base with one more $\mathrm{H^+}$, as with $\mathrm{NH_4^+}$ and $\mathrm{NH_3}$. Option B is tempting because it sounds like a matched pair, but the rule runs the other way: the stronger the acid, the weaker its conjugate base, since an acid that gives up its proton easily leaves behind an ion with little pull to take one back.

43. For the reaction given: HOBr + OH^- ⇌ H_2O + OBr^-, which of the following is the correct conjugated acid-base pair? (1)

A. ✓ **HOBr / OBr^-**

B. OBr^- / OH^-

C. OH^- / H_3O^+

D. OBr^- / H_2O

> **Answer:** A
> A conjugate pair must be two species that differ by one proton. HOBr loses $\mathrm{H^+}$ and becomes $\mathrm{OBr^-}$, so those two belong together. The other pair in this equation is $\mathrm{H_2O}$ with $\mathrm{OH^-}$. Option B is tempting because both of its species appear in the equation, but $\mathrm{OBr^-}$ and $\mathrm{OH^-}$ are two separate bases, not an acid paired with its own base.

44. Given the reaction: H_2O + H_2O ⇌ H_3O^+ + OH^-. How can H_2O act as both an acid and a base? (1)

A. ✓ **By donating a proton and accepting a proton.**

B. By donate a proton only

C. By accepting a proton only

D. By remains neutral

> **Answer:** A
> Water is amphoteric, which means it can act as an acid or as a base. In this autoionisation one water molecule donates a proton and is left as $\mathrm{OH^-}$, while the second water molecule accepts that proton and becomes $\mathrm{H_3O^+}$. Both roles are played at once in the same equation. Option B is tempting because the equation does show a proton being donated, but that proton has to be taken up by something, and the second water molecule is what takes it.

45. A 0.20 M solution of HF has a Ka of 6.6×10^{-4}. How would you determine the pH of this solution? (1)

A. ✓ **Solve [H_3O^+] then use pH = -log[H_3O^+]**

B. Assume [H_3O^+] = [OH^-] and solve pH

C. Use Ka = [HA]/[H_3O^+] to find pH

D. Assume pH = 7 because HF is a weak acid

> **Answer:** A
> HF is a weak acid, so it ionises only partly and $[\mathrm{H_3O^+}]$ has to come from the equilibrium rather than from the label on the bottle. Set up $K_a = x^2/(0.20 - x)$ with $K_a = 6.6 \times 10^{-4}$, solve for x, which comes to about 1.1×10^{-2} M, then take $\mathrm{pH} = -\log[\mathrm{H_3O^+}]$, giving about 1.96. Option D is tempting because the word weak sounds close to neutral, but a weak acid still makes the solution acidic, and pH 7 would mean no ionisation at all.

46. A solution of NaOH has initial concentration of 0.01 M. Calculate the [OH^-] and determines the pOH. (1)

A. ✓ **[OH^-] = 0.01 M, pOH = 2**

B. [OH^-] = 0.01 M, pOH = 3

C. [OH^-] = 0.001 M, pOH = 2

D. [OH^-] = 0.1 M, pOH = 1

> **Answer:** A
> Sodium hydroxide is a strong base and dissociates completely, so every mole put in gives a mole of hydroxide and $[\mathrm{OH^-}] = 0.01$ M. Then $\mathrm{pOH} = -\log(0.01) = 2$. Option B is tempting if the exponent is misread, but $0.01 = 10^{-2}$, and a pOH of 3 would need $[\mathrm{OH^-}] = 0.001$ M.

47. Two solutions A and B have pH values of 2 and 4 respectively. Which of the following is correctly described? (1)

A. Solution A is more basic than solution B.

B. The concentration of H^+ in solution B is 100 times greater than that of solution A.

C. The concentration of H^+ in solution A is 1000 times greater than that of solution B.

D. ✓ **The concentration of H^+ in solution A is 100 times greater than that of solution B.**

> **Answer:** D
> Each pH unit is a factor of ten in $[\mathrm{H}^+]$. Solution A has $[\mathrm{H}^+] = 10^{-2}$ M and solution B has 10^{-4} M, so A is $10^2 = 100$ times more concentrated in hydrogen ions. A lower pH means a more acidic solution. Option B is tempting because the factor of 100 is correct, but it names the wrong solution as the more concentrated one.

48. Which of the following statements best evaluates the impact of increasing temperature on the ionization constant of water? (1)

A. The value of Kw remains unchanged, and the pH of pure water stays constant.

B. ✓ **The value of Kw increases, leading to an increase in both [H_3O^+] and [OH^-].**

C. The value of Kw decreases, reducing the ionization of water and increasing the pH.

D. The value of Kw is unaffected by temperature, but [H_3O^+] and [OH^-] change independently.

> **Answer:** B
> The self ionisation of water absorbs heat, so it is endothermic. Heating pushes an endothermic equilibrium forward, more water molecules split, and K_w grows above 1×10^{-14}. Both $[\mathrm{H_3O^+}]$ and $[\mathrm{OH^-}]$ rise together, so hot pure water has a pH below 7 and is still neutral. Option C is tempting if you assume heating always slows things down, but heat favours the endothermic direction, which here is ionisation.

49. If the pH of a buffer solution is lower than the pKa of its component, which of the following is TRUE? (1)

A. ✓ **The concentration of acid is greater than the conjugate base.**

B. The concentration of acid is less than the conjugate base.

C. The buffer has lost its buffering capacity

D. The solution is neutral

> **Answer:** A
> Use $\mathrm{pH} = \mathrm{p}K_a + \log \dfrac{[\mathrm{A}^-]}{[\mathrm{HA}]}$. If the pH is below the $\mathrm{p}K_a$, the log term has to be negative, so the ratio $[\mathrm{A}^-]/[\mathrm{HA}]$ is less than 1 and the undissociated acid is the larger of the two. Option C is tempting because something sounds out of balance, but a buffer keeps working across roughly one pH unit on either side of its $\mathrm{p}K_a$.

50. Which of the following is NOT a component of a buffer system? (1)

A. A weak acid/strong conjugate base

B. A weak base/strong conjugated acid

C. ✓ **A strong acid/weak conjugated base**

D. A weak base/its salt

> **Answer:** C
> A buffer needs one partner that can absorb added acid and another that can absorb added base, so it is built from a weak acid with its conjugate base, or a weak base with its conjugate acid. A strong acid ionises completely and the conjugate base it leaves is far too weak to take a proton back, so that pair cannot resist a pH change. Option D is tempting because it is worded loosely, but a weak base with its salt is a standard buffer, as with ammonia and ammonium chloride.

51. A buffer solution is prepared by mixing an acid (HA) and its salt (NaA). If the concentration of A^- increases relative to HA, which of the following expressions should be used to determine the resulting pH? (1)

A. pH = log[H^+]
B. ✓ **pH = pKa + log([A^-]/[HA])**
C. pOH = pKa + log([HA]/[A^-])
D. pH = [H^+] × [OH^-]

> **Answer:** B
> The Henderson-Hasselbalch equation, $\mathrm{pH} = \mathrm{p}K_a + \log \frac{[\mathrm{A}^-]}{[\mathrm{HA}]}$, links the pH of a buffer to the ratio of the pair. Raising $[\mathrm{A}^-]$ makes the log term larger, so the pH rises, which is what the question describes. Option C is tempting because it carries the same terms, but it puts pOH on the left and turns the ratio upside down, so it does not give the pH.

52. A buffer solution is made by mixing NH_4Cl and NH_3. Which species will react with added H^+ ions? (1)

A. NH_4^+
B. ✓ **NH_3**
C. Cl^-
D. H_2O

> **Answer:** B
> Added H^+ is taken up by the basic half of the buffer pair. Here that is ammonia: $\mathrm{NH_3} + \mathrm{H}^+ \rightarrow \mathrm{NH_4^+}$, which keeps the pH nearly steady. Option A is tempting because ammonium is the other half of the same buffer, but $\mathrm{NH_4^+}$ already holds the extra proton, so it is the part that answers added base instead.

53. What is the pH of a buffer solution containing equimolar of acetic acid and sodium acetate having pKa = 4.76? (1)

A. 4.46
B. ✓ **4.76**
C. 5.06
D. 7.00

> **Answer:** B
> Equimolar means $[\mathrm{A}^-] = [\mathrm{HA}]$, so the ratio is 1 and $\log 1 = 0$. The Henderson-Hasselbalch equation then leaves $\mathrm{pH} = \mathrm{p}K_a = 4.76$. Option D is tempting because an acid mixed with its own salt sounds balanced, but acetic acid is a weak acid and its buffer sits on the acidic side, not at neutral.

54. A compound having molecular formula C_7H_8 that does not decolorize in Br_2 in CCl_4 or $KMnO_4$ solution most likely belongs to which class of hydrocarbons? (1)

A. Alkynes
B. ✓ **Aromatic hydrocarbons**
C. Alkanes
D. Alkenes

> **Answer:** B
> $\mathrm{C_7H_8}$ is toluene, a benzene ring carrying one methyl group. Bromine in $\mathrm{CCl_4}$ and $\mathrm{KMnO_4}$ both test for multiple bonds that give their electrons up easily, and an aromatic ring holds its delocalised electrons too tightly to add across them, so neither reagent loses its colour. Option D is tempting because an aromatic ring is drawn with double bonds, but a real alkene would decolourise both reagents at once.

55. Which of the following salts undergoes anionic hydrolysis, resulting in a basic solution? (1)

A. ✓ **Sodium formate (HCOONa)**
B. Potassium chloride (KCl)
C. Sodium sulfate (Na_2SO_4)
D. Ammonium nitrate (NH_4NO_3)

> **Answer:** A
> Sodium formate is made from a weak acid, methanoic acid, and a strong base. In water the formate ion takes a proton back from a water molecule: $\mathrm{HCOO^-} + \mathrm{H_2O} \rightleftharpoons \mathrm{HCOOH} + \mathrm{OH^-}$. The extra hydroxide makes the solution basic. Option D is tempting because ammonium nitrate also hydrolyses, but there it is the cation $\mathrm{NH_4^+}$ that reacts, and the solution turns acidic.

56. A student prepares a 2.0 M HCl solution by dissolving hydrochloric acid in water. If they were to prepare the same molarity solution using sulfuric acid (H_2SO_4), what would be its normality? (1)

A. 1.0 N
B. 2.0 N
C. ✓ **4.0 N**
D. 3.0 N

> **Answer:** C
> Normality is molarity multiplied by the number of reacting units each formula supplies. Sulfuric acid gives two H^+ per molecule, so $N = 2.0 \times 2 = 4.0$ N. Option B is tempting because the molarity is 2.0, but molarity and normality are equal only for an acid that supplies one proton, such as HCl.

57. What is the sum of coefficients of reactants and products after the following ionic equation gets balanced in acidic media? $MnO_4^- + Fe^{2+} \rightarrow Mn^{2+} + Fe^{3+}$ (1)

A. 19
B. 23
C. ✓ **24**
D. 10

> **Answer:** C
> Balance the half reactions in acid. Manganese falls from $+7$ to $+2$, a gain of 5 electrons, while each iron rises from $+2$ to $+3$, losing 1, so 5 Fe^{2+} are needed. Balancing oxygen with water and hydrogen with H^+ gives $MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$. Adding every coefficient: $1 + 5 + 8 + 1 + 5 + 4 = 24$. Option D is far too small because it leaves out the eight H^+ and four H_2O that acidic conditions require, and those alone contribute 12.

58. What is the difference between electrolytic cell and galvanic cell? (1)

A. In a galvanic cell, non-spontaneous chemical reactions take place.
B. ✓ **In an electrolytic cell, non-spontaneous chemical reactions take place.**
C. In a galvanic cell, the anode is positive and the cathode is negative.
D. Galvanic cells convert electrical energy into chemical energy.

> **Answer:** B
> A galvanic cell runs a reaction that happens by itself and turns chemical energy into electrical energy, as a torch battery does. An electrolytic cell works the other way round: an outside power supply forces through a reaction that would never run on its own, such as splitting molten sodium chloride into its elements. Option A is tempting because it names the same idea, but it attaches it to the wrong cell.

59. What is the half-reaction at the anode during the electrolysis of copper sulfate ($CuSO_4$) solution using copper electrode? (1)

A. $Cu^{2+} + 2e^- \rightarrow Cu$
B. ✓ **$Cu \rightarrow Cu^{2+} + 2e^-$**
C. $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
D. $2Cl^- \rightarrow Cl_2 + 2e^-$

> **Answer:** B
> With a copper anode the electrode metal is easier to oxidise than either water or the sulfate ion, so the anode itself dissolves: $Cu \rightarrow Cu^{2+} + 2e^-$. This is how copper is refined, since the impure anode wastes away while pure copper plates onto the cathode. Option C is tempting because oxygen is released at the anode in many electrolysis experiments, but that happens with an inert electrode such as platinum, not with one made of copper.

60. Which of the following is the correct increasing order of the atomic size of: Mg^+, Na, Si^{3+}, and Al^{2+}? (1)

A. Na < Mg^+ < Al^{2+} < Si^{3+}

B. Al^{2+} < Mg^+ < Na < Si^{3+}

C. ✓ **Si^{3+} < Al^{2+} < Mg^+ < Na**

D. Si^{3+} > Al^{2+} > Na > Mg^+

Answer: C

Count the electrons first. Na has 11, Mg^+ has $12 - 1 = 11$, Al^{2+} has $13 - 2 = 11$ and Si^{3+} has $14 - 3 = 11$. All four are isoelectronic, so the same 11 electrons are being held by a nucleus of growing charge. More protons pull the same electron cloud in tighter, so the particle shrinks as you move along, and the increasing order of size is $Si^{3+} < Al^{2+} < Mg^+ < Na$. Option A is tempting because it lists the species in periodic table order, but with the electron count fixed, extra nuclear charge makes a particle smaller, not larger.

61. What gases are produced at the cathode and anode respectively if concentrated hydrochloric acid is electrolyzed? (1)

A. Hydrogen gas and Oxygen gas

B. Chlorine gas and oxygen gas

C. ✓ **Hydrogen and chlorine**

D. Hydrogen and water

Answer: C

Concentrated hydrochloric acid holds a great deal of chloride ion. At the cathode H^+ is reduced to hydrogen gas. At the anode the high chloride concentration lets Cl^- be oxidised in preference to water, so chlorine gas comes off. Option A is tempting because oxygen does appear at the anode when the acid is dilute, but with concentrated chloride present the chloride is discharged first.

62. Which of the following best describes a line spectrum? (1)

A. Continuous range of colors without any gap.

B. ✓ **A spectrum that shows only specific wavelengths of light.**

C. A spectrum emitted only by solids at high temperature.

D. A black and white representation of visible light.

Answer: B

Electrons in an atom may hold only certain fixed energies. When an excited electron drops back, it gives out a photon whose energy is exactly the size of the gap, so only a few particular wavelengths leave the atom. On a screen they show as separate bright lines with darkness between them, which is why every element has its own fingerprint. Option A is tempting because a hot solid does give an unbroken band of colour, but that is a continuous spectrum, the opposite of a line spectrum.

63. What are the volume of H_2 and O_2 gases at 25°C and 1.00 atm that will be collected at the cathode and anode, respectively if Na_2SO_4(aq) solution is electrolyzed for 2 hours with 10 amperes current? (1)

A. 9 L of oxygen and 4.5 L of hydrogen

B. 6 L of oxygen and 12 L of hydrogen

C. ✓ **9 L of hydrogen and 4.5 L of oxygen**

D. Equal volume of oxygen and hydrogen gases are produced

Answer: C

First find the charge: $Q = It = 10 \times 7200 = 72000$ C, so the moles of electrons are $72000 \div 96500 = 0.746$ mol. Sodium sulfate solution electrolyses as water. Hydrogen needs 2 electrons per molecule, giving $0.746 \div 2 = 0.373$ mol, and oxygen needs 4, giving $0.746 \div 4 = 0.187$ mol. Then $V = nRT/P$ at 298 K and 1 atm gives about $0.373 \times 0.0821 \times 298 = 9.1$ L of hydrogen at the cathode and about 4.6 L of oxygen at the anode. Option A carries the same two numbers with the gases swapped, but hydrogen is the one produced in double the amount, and it forms at the cathode.

64. A student is tasked with calculating the mass of copper deposited when a current is passed through a copper(II) sulfate solution for 3 hours using 5 amperes of current. Using Faraday's second law of electrolysis, how would they derive the formula for mass of copper deposited in terms of current, time, and the equivalent mass of copper? (1)

A. m = V i t

B. ✓ **m = M I t / n F**

C. m = z Q

D. m = n F

> **Answer:** B
> Faraday's laws connect the mass deposited to the charge passed. Charge is $Q = It$, the moles of electrons are It/F, and n electrons are needed per atom of metal, so the moles of copper are It/nF. Multiplying by the molar mass M gives $m = \frac{MIt}{nF}$, in which M/n is the equivalent mass the question asks about. Option C, $m = zQ$, is not wrong in spirit, since z is the electrochemical equivalent, but it hides the current and the time inside Q and does not express the answer in the terms the question names.

65. What is the primary function of a sacrificial anode in corrosion protection? (1)

A. To increase the rate of corrosion in metal structures.

B. To facilitate the oxidation reaction of other metal keeping itself at cathode.

C. ✓ **To sacrifice itself to protect another metal from corrosion.**

D. To enhance the electrical conductivity of the protected metal

> **Answer:** C
> A sacrificial anode is a block of a more reactive metal, usually zinc or magnesium, attached to the structure being protected. Because it gives up electrons more readily than iron, it corrodes in the iron's place while the iron stays cathodic and intact. The block has to be replaced from time to time, which is where the name comes from. Option B is tempting because it also mentions oxidation, but it puts the sacrificial metal at the cathode, and the metal that is oxidised is always the anode.

66. When a piece of metal A is placed in a solution containing ions of B, metal B plates out on the piece of A. Which metal is being oxidized and reduced respectively? (1)

A. ✓ **Metal A and metal B**

B. Metal B and metal A

C. Both metal A and metal B are equally reduced

D. Both metal A and metal B are equally oxidized

> **Answer:** A
> Metal B appears as a solid coating, so B^{n+} ions have taken electrons and been reduced. Those electrons had to come from somewhere, and they come from metal A, which dissolves into the solution as ions. So A is oxidised and B is reduced, and the more reactive metal has displaced the less reactive one. Option B is tempting because B is the metal we can see appearing, but turning an ion into a metal is a gain of electrons, which is reduction, not oxidation.

67. Given the reaction: Mg(s) + Zn^{2+}(aq) → Mg^{2+}(aq) + Zn(s). Which of the following is the correct cell notation? (1)

A. Zn^{2+}(aq)/Zn(s) // Mg(s)/Mg^{2+}(aq)

B. Zn^{2+}(aq)/Zn(s) // Mg^{2+}(aq)/Mg(s)

C. Mg(s)/Mg^{2+}(aq) // Zn(s)/Zn^{2+}(aq)

D. ✓ **Mg(s)/Mg^{2+}(aq) // Zn^{2+}(aq)/Zn(s)**

> **Answer:** D
> In cell notation the anode is written on the left, the cathode on the right, and the double line in the middle stands for the salt bridge. Magnesium is oxidised, so its half cell starts from the solid and is written $\mathrm{Mg(s)/Mg^{2+}(aq)}$. Zinc ion is reduced, so its half cell ends at the solid and is written $\mathrm{Zn^{2+}(aq)/Zn(s)}$. Option C is tempting because it puts magnesium on the correct side, but it writes the zinc half backwards, with the solid before its ion.

68. Which of the following is TRUE about the reaction given below? $2Au(s) + 3Ca^{2+}(0.1M) \rightarrow 2Au^{3+}(0.1M) + 3Ca(s)$ (1)

A. There are a total of 2 electron transfer in overall reaction

B. The value of ΔG° is large positive value making the reaction spontaneous

C. ✓ **The forward reaction is non-spontaneous**

D. Gold can reduce calcium spontaneously

> **Answer:** C
> Gold sits far below calcium in reactivity. Standard reduction potentials are about $+1.50$ V for $\mathrm{Au^{3+}/Au}$ and about -2.87 V for $\mathrm{Ca^{2+}/Ca}$, so $E^{\circ}_{cell} = -2.87 - 1.50 = -4.37$ V. A negative cell potential means a positive ΔG°, so the forward reaction does not run on its own. Option B is tempting because it also spots the positive ΔG°, but a positive ΔG° means non-spontaneous, which is the opposite of what B claims.

69. How does industrial chemistry contribute to environmental sustainability? (1)

A. By promoting the excessive use of fossil fuel.

B. ✓ **By developing eco-friendly materials and sustainable production processes.**

C. By increasing chemical waste production.

D. By reducing the use of recycling methods in manufacturing.

> **Answer:** B
> Industrial chemistry helps the environment when it designs cleaner routes: less waste, safer solvents, catalysts that cut the energy a process needs, and materials that can be recycled or that break down harmlessly. That is what green chemistry means in practice. Option A is tempting because industry does burn a great deal of fuel, but burning more fossil fuel damages the environment, so it cannot be the contribution the question is asking for.

70. Which one of the following best describes the formation of pi (π) bond? (1)

A. ✓ **They are formed by sideways overlap of p orbitals.**

B. They are formed by the axial overlaps of s or d orbitals.

C. They are formed by the sideways overlaps of an s and p orbitals.

D. They are formed by the parallel overlaps of either s or p orbitals.

> **Answer:** A
> A pi bond forms when two p orbitals lie parallel to each other and overlap side on, giving electron density above and below the line joining the two nuclei. This sideways overlap is smaller than the head on overlap of a sigma bond, so the pi bond is weaker, and it is the part of a double bond that reacts. Option B is tempting because axial overlap is a real description, but head on overlap along the bond axis produces a sigma bond.

71. Which of the following are the correct steps in sulfuric acid (98%) manufacturing process? (1)

A. $S \rightarrow SO_2 \rightarrow H_2S_2O_2 \rightarrow H_2SO_4$

B. $S \rightarrow SO_2 \rightarrow SO_3 \rightarrow H_2S_2O_2 \rightarrow H_2SO_4$

C. ✓ **$S \rightarrow SO_2 \rightarrow SO_3 \rightarrow H_2S_2O_7 \rightarrow H_2SO_4$**

D. $S \rightarrow SO_2 \rightarrow SO_3 \rightarrow H_2S_2O_7 \rightarrow H_2SO_3$

> **Answer:** C
> The contact process burns sulfur to SO_2, oxidises that over a vanadium(V) oxide catalyst to SO_3, then absorbs the SO_3 into concentrated sulfuric acid to make oleum, $H_2S_2O_7$. Diluting the oleum with the right amount of water gives 98% sulfuric acid. Absorbing into acid rather than into water is done because SO_3 in water forms an unmanageable mist. Option B is tempting because its first steps match, but it writes the intermediate as $H_2S_2O_2$, and oleum is $H_2S_2O_7$.

72. In which of the following aqueous solution provides the same electrolysis with water, when O_2 and H_2 are formed at anode and cathode respectively? (1)

A. Concentrated HCl solution
B. $AgNO_3$ solution
C. $CuSO_4$ solution
D. ✓ **Diluted H_2SO_4 solution**

> **Answer:** D
> The sulfate ion is very hard to oxidise, so in dilute sulfuric acid it is water that reacts at both electrodes: oxygen is released at the anode and hydrogen at the cathode. The acid only makes the solution conduct. Option A is tempting because hydrogen appears at the cathode there too, but concentrated hydrochloric acid gives chlorine at the anode rather than oxygen.

73. Thermoplastic polymers are those which melt when heated and re-solidify when cooled. Which of the following polymers is NOT a thermoplastic polymer? (1)

A. Dacron
B. ✓ **Bakelite**
C. Polyethylene
D. Teflon

> **Answer:** B
> Bakelite is made by heating phenol with methanal, and the chains link across to one another in every direction. Those cross links lock the shape in place, so heating chars the material instead of softening it. That makes Bakelite a thermoset, not a thermoplastic. Option A is tempting because Dacron is stiff and hard wearing, but its chains lie separately alongside each other, so it does soften and melt when heated.

74. What is the molar mass of a polyethylene sample, $[\text{-}CH_2\text{-}CH_2\text{-}]_n$, when n = 4600? (Atomic mass H=1, C=12). (1)

A. 1.288×10^3 g/mol
B. ✓ **1.288×10^5 g/mol**
C. 1.196×10^3 g/mol
D. 1.196×10^4 g/mol

> **Answer:** B
> One repeat unit $-\mathrm{CH_2}-\mathrm{CH_2}-$ holds 2 carbons and 4 hydrogens, so its mass is $2(12)+4(1)=28$ g/mol. Multiply by the number of units: $28\times4600=128800$ g/mol, which is written 1.288×10^5 g/mol. Option A has the right digits but the wrong power of ten, and 1.288×10^3 g/mol would be a chain of only 46 units.

75. Given the monomers: i. $HO\text{-}CH_2CH_2\text{-}OH$; ii. $HOOC\text{-}CH_2CH_2\text{-}COOH$. Which of the following polymer can be synthesized from these monomers? (1)

A. ✓ **$[\text{-O-}CH_2CH_2\text{-OOC-}CH_2\text{-}CH_2\text{-CO-}]n$**
B. $[\text{-OC-}C_6H_4\text{-COO-}(CH_2)_2\text{O-}]$
C. $[\text{-}NH_2CH(R)(COOH)\text{-}]$
D. $[\text{-NH-}CH_2\text{-CO-NH-}CH_2CO\text{-}]$

> **Answer:** A
> This is a condensation polymerisation between a diol and a dicarboxylic acid. Each OH meets a COOH, a water molecule leaves, and an ester link $-\mathrm{COO}-$ forms, joining unit to unit into a polyester chain. Following the two monomers through gives the repeat unit $[-\mathrm{O}-\mathrm{CH_2CH_2}-\mathrm{OOC}-\mathrm{CH_2CH_2}-\mathrm{CO}-]_n$. Option B is tempting because it is also a polyester, but its acid half carries a benzene ring, and neither monomer given here contains one.

76. An unknown salt when heated with a Bunsen flame produced a bright-yellow flame. An aqueous solution of this salt when reacted with dilute HCl released a gas that turns limewater milky. Upon addition of calcium chloride solution to an aqueous solution of this salt, a white precipitate is formed. What is the unknown salt? (1)

A. ✓ **Na_2CO_3**
B. NH_4NO_3
C. $Al_2(SO_4)_3$
D. CH_3COOH

> **Answer:** A
> Take the three tests one at a time. A bright yellow flame is the flame test for sodium. A gas that turns limewater milky is carbon dioxide, and dilute acid releases carbon dioxide from a carbonate. Adding calcium chloride then gives a white precipitate of calcium carbonate, which is insoluble. Sodium carbonate is the one salt that passes all three tests. Option B is tempting because ammonium nitrate is also a soluble white salt, but it gives no yellow flame and releases no gas with dilute acid.

— END OF MARKING KEY —

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