

The law of definite proportion says a pure compound always holds the same elements in the same fixed mass ratio, whatever its source. Chalk always giving calcium, carbon and oxygen in a 10:3:12 mass ratio is exactly that. B is tempting, but comparing two different compounds of the same elements, P_4O_{10} against P_4O_6 , is the law of multiple proportions.

4. The statement 'The properties of the elements are periodic functions of their atomic masses' is the (1)
- A. Law of mass action
B. ✓ **Mendeleev's periodic law**
C. Modern periodic law
D. Law of definite proportion

Answer: B

Mendeleev lined the elements up by increasing atomic mass and saw their properties repeat at regular intervals. That is his periodic law. C is the tempting answer, but the modern periodic law makes properties a function of atomic number, not atomic mass, and that change is what fixed the places where Mendeleev's order broke down.

5. What was the main conclusion of the Rutherford Gold Foil Experiment conducted by Ernest Rutherford? (1)
- A. Electrons carry a negative charge.
B. A proton is a hydrogen atom without an electron.
C. Electrons move around the nucleus in fixed orbits.
D. ✓ **Most of the mass and all the positive charge of an atom are concentrated in a very small nucleus**

Answer: D

Most alpha particles passed straight through the gold foil, but a few came back at sharp angles. Rutherford read that to mean the atom is mostly empty space with all its positive charge and nearly all its mass packed into a very small centre, the nucleus. C is tempting, but the idea of fixed orbits came later from Bohr, not from this experiment.

6. The number of protons, neutrons and electrons respectively in Cd^{2+} are _____. (1)
- A. 48, 64, 48
B. ✓ **48, 64, 46**
C. 48, 64, 50
D. 48, 63, 46

Answer: B

Cadmium has atomic number 48, so every cadmium particle has 48 protons. The isotope in the question has mass number 112, so the neutron count is $112 - 48 = 64$. The $2+$ charge means two electrons were lost, leaving $48 - 2 = 46$. A is tempting if you keep the electron count equal to the proton count, but that is only true for a neutral atom, not for an ion.

7. To which group and periods of the periodic table does an element with atomic number 33 belong? (1)
- A. Group IIIB and period 4
B. Group IIIA and period 4
C. ✓ **Group VA and period 4**
D. Group IV and period 4

Answer: C

Element 33 fills as $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3$. The highest occupied shell is $n = 4$, which puts it in period 4. Its outer shell holds $4s^2 4p^3$, five valence electrons in a main group position, so it belongs to group VA. B is tempting if you count only the three p electrons and read the group as IIIA.

8. An element X has two naturally occurring isotopes. The information about these isotopes is given in the table below. Isotope X-40 (Atomic Mass 40 u, Natural Abundance 80%) and Isotope X-44 (Atomic Mass 44 u, Natural Abundance 20%). What is the average atomic mass of element X? (1)
- A. ✓ **40.8 u**
B. 41.5 u
C. 40.0 u
D. 42.0 u

Answer: A

Average atomic mass is the weighted average over the isotopes, so multiply each mass by its abundance and add. $0.80 \times 40 + 0.20 \times 44 = 32 + 8.8 = 40.8$ u. C is tempting because 40 is the mass of the common isotope, but the heavier isotope still pulls the average above 40.

9. In which of the following blocks of the periodic table does an element with atomic number 16 located? (1)

- A. s B. ✓ p
C. d D. f

Answer: B

Element 16 is sulfur, with the configuration $1s^2 2s^2 2p^6 3s^2 3p^4$. The last electron to be added goes into a $3p$ orbital, so sulfur sits in the p block. A is tempting because sulfur does have a full $3s$ subshell, but a block is named after the subshell that receives the final electron, not after a subshell that filled earlier.

10. All of the following compounds contain ionic and covalent bonds except: (1)

- A. NH_4Cl B. CaCO_3
C. ✓ NH_3BF_3 D. Na_3PO_4

Answer: C

In NH_4Cl , $CaCO_3$ and Na_3PO_4 a polyatomic ion is held together inside by covalent bonds, and that ion is held to its partner ion by an ionic bond, so each has both bond types. In H_3N-BF_3 the nitrogen donates its lone pair to boron, which is a dative covalent bond, and no ions are formed at all. A is tempting because ammonium looks like a molecule, but NH_4^+ and Cl^- are separate ions.

11. Which of the following molecules considered to be a polar molecule? (1)

- A. ✓ NH₃
B. BF₃
C. CO₂
D. CCl₄

Answer: A

Ammonia is trigonal pyramidal because nitrogen keeps one lone pair alongside its three bonds. The three N to H bond dipoles all point the same general way and the lone pair adds to them, so they do not cancel and the molecule is polar. BF_3 is the tempting choice since its B to F bonds are strongly polar, but the molecule is flat and symmetrical, so those three dipoles cancel exactly.

12. Which one of the following molecules does not contain dative bond? (1)

- A. H₃O⁺
B. ✓ NH₃
C. NH₃BF₃
D. NH₄⁺

Answer: B

A dative bond forms when one atom supplies both electrons of a shared pair. H_3O^+ , NH_4^+ and H_3N-BF_3 all form that way, from a lone pair on oxygen or nitrogen. In ammonia itself each N to H bond takes one electron from nitrogen and one from hydrogen, so all three are ordinary covalent bonds. D is tempting because ammonium contains ammonia, but it is the fourth bond, the one made from the lone pair, that is dative.

13. The attraction force which is created by a temporary redistribution of electrons in neighboring atom is called? (1)

- A. Hydrogen bond
B. ✓ London dispersion
C. Dipole-dipole
D. Ionic bond

Answer: B

Electrons keep moving, so for an instant they can sit more on one side of an atom than the other. That momentary dipole pulls on the electrons of a neighbouring atom and induces a dipole there, and the two attract. This weak, short lived attraction is the London dispersion force. C is tempting, but a dipole to dipole force needs molecules that are permanently polar, not momentarily so.

14. Which one of the following does the sulphur atom have the lowest oxidation number? (1)
- A. SO_3 B. S_2F_{10}
C. H_2SO_3 D. ✓ H_2S

Answer: D

Work out the oxidation number of sulfur in each compound. It is +6 in SO_3 , +5 in S_2F_{10} , +4 in H_2SO_3 and -2 in H_2S . The lowest of these is -2. H_2SO_3 is the tempting answer because +4 is the smallest of the positive values, but sulfur only goes negative when it is the more electronegative partner, which happens with hydrogen alone.

15. The concept like dissolves like is illustrated by which of the following? (1)
- A. NaCl is more soluble in CCl_4 than water B. ✓ **I_2 is more soluble in CCl_4 than water**
C. CuSO_4 is more soluble in CCl_4 than water D. CCl_4 soluble in water

Answer: B

Like dissolves like means a polar solvent dissolves polar and ionic solutes while a nonpolar solvent dissolves nonpolar ones. Iodine, I_2 , is nonpolar and carbon tetrachloride is nonpolar, so iodine dissolves well in CCl_4 and hardly at all in water. A is tempting, but sodium chloride is ionic and needs polar water molecules to pull its ions apart.

16. What is the mole fraction of methanol (CH_3OH) in a mixture of equal mass of methanol and water? (1)
- A. ✓ **0.36** B. 0.64
C. 0.53 D. 0.44

Answer: A

Equal masses, so take 100 g of each. Moles of methanol = $100/32 = 3.125$ and moles of water = $100/18 = 5.556$, giving a total of 8.681 mol. The mole fraction of methanol is $3.125/8.681 = 0.36$. B is the tempting answer because 0.64 is the mole fraction of the water, and the two must add to 1.

17. Which of the following acid is a monoprotic acid? (1)
- A. H_2SO_4 B. ✓ **CH_3COOH**
C. H_3PO_4 D. H_2CO_3

Answer: B

A monoprotic acid releases one proton per molecule. Acetic acid, CH_3COOH , carries four hydrogens, but only the one on the $-\text{COOH}$ group is acidic, so it gives up only one H^+ . H_2SO_4 is the tempting pick because its first proton comes off easily, but it goes on to release a second one, which makes it diprotic.

18. Student A and Student B are grade 12 students. They carry out laboratory experiment on detection of metallic ions in different salts as per their laboratory assistance intended them to do so. Student A achieved yellow color after he carry out the flame tests of different salts whereas Student B obtained green color from the same tests on different salts. Which ions did Student A and Student B detected respectively? (1)
- A. Ca^{2+} & K^+ B. ✓ **Na^+ & Ba^{2+}**
C. Ca^{2+} & Mg^{2+} D. Ba^{2+} & Li^+

Answer: B

In a flame test each metal ion gives its own colour as excited electrons drop back down. Sodium gives a strong yellow flame and barium gives a pale green one, so Student A found Na^+ and Student B found Ba^{2+} . D is tempting because barium appears in it, but the order in the question matters: barium is the green one, not the yellow one, and lithium burns red.

19. Which of the following is an example of double displacement reaction? (1)
- A. $\text{Cl}_2 + 2\text{KI} \rightarrow 2\text{KCl} + \text{I}_2$ B. $\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}$
- C. $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$ D. ✓ **$\text{NaCl} + \text{AgNO}_3 \rightarrow \text{AgCl} + \text{NaNO}_3$**

Answer: D

In a double displacement reaction two compounds swap partners. $\text{NaCl} + \text{AgNO}_3$ gives AgCl and NaNO_3 : sodium takes the nitrate, silver takes the chloride, and the insoluble silver chloride drops out as a precipitate. A is tempting because two compounds appear on each side, but there chlorine pushes iodine out on its own, which makes it a single displacement.

20. Which of the following is correct statement about endothermic reaction? (1)
- A. Heat energy is written in the right side of the equation
- B. Enthalpy change of the reaction has a negative value
- C. Chemical reaction that releases heat energy to the surrounding.
- D. ✓ **Heat is absorbed to the system from the surrounding.**

Answer: D

An endothermic reaction takes heat in from the surroundings. Because the system gains energy, ΔH is positive and the heat term is written on the reactant side of the equation. C is the tempting statement, but a reaction that releases heat to the surroundings is exothermic, which is the opposite case.

21. The two gaseous elements that can be obtained from atmosphere by fractional distillation of liquid air are: (1)
- A. Nitrogen and hydrogen B. Oxygen and hydrogen
- C. ✓ **Nitrogen and oxygen** D. Ammonia and carbon dioxide

Answer: C

Air is mostly nitrogen and oxygen. Cooling air until it liquefies and then letting it warm slowly separates the two, because nitrogen boils at about -196°C and oxygen at about -183°C , so the nitrogen comes off first. A is tempting, but the atmosphere holds almost no free hydrogen, so there is nothing to collect.

22. According to Markovnikov's rule, the alcohol produced from propene, $\text{CH}_2=\text{CH}-\text{CH}_3$, during the addition of water in the presence of acid catalyst is (1)
- A. ✓ **2-propanol** B. 1-propanol
- C. Hexanol D. 2-hexanol

Answer: A

Markovnikov's rule says that when water adds across a double bond, the hydrogen goes to the carbon that already carries more hydrogens. In $\text{CH}_2 = \text{CH}-\text{CH}_3$ that is the end carbon, so the OH lands on the middle carbon and the product is 2-propanol. B is tempting, but 1-propanol is the anti-Markovnikov product and needs a different reaction to make it.

23. Which of the following molecules does not exhibit geometrical isomerism? (1)
- A. 2-butene B. ✓ **1-butene**
- C. 3-hexene D. 1,2-dichloro ethene

Answer: B

Geometrical isomerism needs each carbon of the double bond to carry two different groups. In 1-butene, $\text{CH}_2 = \text{CH}-\text{CH}_2\text{CH}_3$, the first carbon carries two hydrogens, so swapping them gives back the same molecule and no cis or trans forms exist. A is tempting because 2-butene looks similar, but there each double bond carbon holds one H and one CH_3 , so cis and trans really are two different compounds.

24. Among the following methods, which one can be used to prepare alkyne in the laboratory? (1)
- A. Dehydration of alcohols with concentrated H_2SO_4
 - B. Hydrogenation of alkene with a metal catalyst.
 - C. Dehydrohalogenation of alkyl halides with a base
 - D. ✓ **Dehydrohalogenation of Vicinal dihalides with a base.**

Answer: D

A vicinal dihalide carries a halogen on each of two neighbouring carbons. A strong base removes HX once to give a vinyl halide and then a second time to give the triple bond, so an alkyne is formed. C is tempting, but an ordinary alkyl halide carries only one halogen, so a single elimination gives an alkene and the reaction stops there.

25. What is the wavelength of a photon emitted when a hydrogen atom undergoes a transition from $n=5$ to $n=2$? (1)
- A. 434 mm
 - B. 434 pm
 - C. ✓ **434 nm**
 - D. 434 μm

Answer: C

Use the Rydberg equation, $\frac{1}{\lambda} = R \left(\frac{1}{2^2} - \frac{1}{5^2} \right)$ with $R = 1.097 \times 10^7 \text{ m}^{-1}$. That gives $\frac{1}{\lambda} = 1.097 \times 10^7 \times 0.21 = 2.30 \times 10^6 \text{ m}^{-1}$, so $\lambda = 4.34 \times 10^{-7} \text{ m}$, which is 434 nm. All four options share the number 434, so the unit is what is being tested. B is the trap: a picometre is 10^{-12} m , which would make this an X-ray, not the visible line the Balmer series gives.

26. For the four quantum numbers needed to describe an electron, which of these combinations are not possible? (1)
- A. (1, 0, 0, +1/2)
 - B. (2, 1, 1, -1/2)
 - C. (3, 2, -2, -1/2)
 - D. ✓ **(1, 0, -1, +1/2)**

Answer: D

The quantum numbers are tied to each other. For $n = 1$ the only allowed value of l is 0, and when $l = 0$ the only allowed value of m_l is 0. The set (1, 0, -1, +1/2) breaks that rule, because m_l cannot be -1 when l is 0. C looks risky because of its negative values, but with $l = 2$ the allowed m_l values run from -2 to +2, so it is fine.

27. Which of the following is the most stable electronic configuration for the element 24Cr? (1)
- A. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$
 - B. ✓ **$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$**
 - C. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$
 - D. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^2$

Answer: B

Chromium has 24 electrons. Filling strictly in order would end with $4s^2 3d^4$, but shifting one 4s electron into the d set gives $4s^1 3d^5$, which leaves both the 4s and the 3d half filled. Half filled subshells are more stable, so this is chromium's real ground state. A is tempting because it follows the filling order exactly, but chromium is one of the standard exceptions to that order.

28. Which pairs of molecules is geometrically similar? (1)
- A. CF_4 and SF_4
 - B. NCl_3 and BF_3
 - C. CO_2 and OF_2
 - D. ✓ **NH_3 and PH_3**

Answer: D

Both NH_3 and PH_3 have a central atom with three bonding pairs and one lone pair, so both come out trigonal pyramidal. B is the tempting pair, because NCl_3 does have a lone pair and is pyramidal, but boron in BF_3 has no lone pair at all, so BF_3 is trigonal planar and the two shapes do not match.

34. The rate of a chemical reaction will be increased by all of the following factors EXCEPT. (1)
- A. ✓ the presence of a high activation energy
 - B. increasing the surface area of a reactant
 - C. the presence of a catalyst
 - D. an increase in temperature

Answer: A

Activation energy is the energy hill the reactants must climb before they can react. A high hill means fewer collisions carry enough energy, so the reaction runs slower. The other three all speed a reaction up: more surface area gives more contact, heat gives particles more energy, and a catalyst lowers the hill. C is tempting only if a catalyst is confused with something used up, but a catalyst always lowers the activation energy and speeds the reaction.

35. What is the process that converts liquid vegetable oils to solid fats? (1)
- A. Hydration
 - B. ✓ Hydrogenation
 - C. Hydrolysis
 - D. Saponification

Answer: B

Vegetable oils contain carbon to carbon double bonds, which put kinks in the chains and keep them from packing closely. Adding hydrogen across those double bonds over a nickel catalyst makes the chains saturated and straight, so they pack together and the oil becomes a solid fat. D is tempting because saponification also starts from oils, but it breaks them apart into soap and glycerol instead of hardening them.

36. The correct relationship between K_c and K_p for the reaction $\text{CO(g)} + \text{H}_2\text{O(g)} \leftrightarrow \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$ at equilibrium is (1)
- A. $K_p = K_c(RT)^2$
 - B. $K_p = K_c(RT)$
 - C. ✓ $K_p = K_c$
 - D. $K_p = K_c(RT)^4$

Answer: C

The link between the two constants is $K_p = K_c(RT)^{\Delta n}$, where Δn is the moles of gas on the right minus the moles of gas on the left. Here there are 2 moles of gas on each side, so $\Delta n = 0$ and $(RT)^0 = 1$, which leaves $K_p = K_c$. B is tempting if you count the total moles of gas instead of the difference between the two sides.

37. When propene, C_3H_6 undergo a complete combustion reaction, what will be the coefficient of oxygen? (1)
- A. ✓ 9
 - B. 6
 - C. 4
 - D. 3

Answer: A

Complete combustion sends every carbon to CO_2 and every hydrogen to H_2O , so C_3H_6 gives $3\text{CO}_2 + 3\text{H}_2\text{O}$. That needs $6 + 3 = 9$ oxygen atoms, which is 4.5 molecules of O_2 . Doubling everything clears the half: $2\text{C}_3\text{H}_6 + 9\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$, so the coefficient of oxygen is 9. B is tempting because six oxygen atoms go into the carbon dioxide, but the water still needs three more.

38. The percentage ionization of a 0.01 mol/L weak acid HA solution whose pH is 4 is (1)
- A. 0.1%
 - B. ✓ 1%
 - C. 2.5%
 - D. 4%

Answer: B

A pH of 4 means $[\text{H}^+] = 1 \times 10^{-4}$ mol/L, and that is how much of the acid has ionized. Percentage ionization is the ionized part over the starting concentration: $\frac{10^{-4}}{10^{-2}} \times 100 = 1\%$. A is tempting if one power of ten slips in the division, since 10^{-4} over 10^{-2} is 10^{-2} , not 10^{-3} .

39. The pH from the titration of weak acid and strong base at the equivalent point is ----- (1)
- A. below 7
B. equal to 7
C. ✓ above 7
D. not determined

Answer: C

At the equivalence point every molecule of the weak acid has been converted into its conjugate base, for example CH_3COOH into CH_3COO^- . That base then takes a proton from water and leaves OH^- behind, so the solution is basic and the pH sits above 7. B is tempting because equal moles have reacted, but a pH of exactly 7 happens only when a strong acid meets a strong base and neither product hydrolyses.

40. The conjugate base and conjugate acid for hydrogen carbonate ion, HCO_3^- respectively is (1)
- A. CO_3^{2-} and HCO_3^-
B. H_2CO_3 and CO_3^{2-}
C. ✓ CO_3^{2-} and H_2CO_3
D. HCO_3^- and H_2CO_3

Answer: C

A conjugate base is what is left after a species loses H^+ , so HCO_3^- becomes CO_3^{2-} . A conjugate acid is what forms after it gains H^+ , so HCO_3^- becomes H_2CO_3 . B is tempting because it names both of the right species, but it has them the wrong way round.

41. The dissociation constant of a weak acid is 1×10^{-4} . In order to prepare a buffer solution with a pH = 5, the (acid)/(salt) ratio should be (1)
- A. ✓ 1:10
B. 4:5
C. 10:1
D. 5:4

Answer: A

Use $pH = pK_a + \log \frac{[salt]}{[acid]}$. First $pK_a = -\log(1 \times 10^{-4}) = 4$, so $5 = 4 + \log \frac{[salt]}{[acid]}$ and the log term is 1. That makes salt to acid 10 : 1, so acid to salt is 1 : 10. C is the trap: it is the same ratio written backwards, and the question asks for acid over salt.

42. What is the product for the following reaction given below? $CH_3CH_2CH_2COOCH_2CH_3$ with $LiAlH_4$ (1)
- A. $CH_3CH_2CH_2COOH$ & CH_3CH_2OH
B. ✓ $CH_3CH_2CH_2CH_2OH$ & CH_3CH_2OH
C. $CH_3CH_2CH_2COOH$ & CH_3COOH
D. $CH_3CH_2CH_2CHO$ & CH_3CH_2OH

Answer: B

Lithium aluminium hydride is a strong reducing agent that attacks the ester group and cuts it in two. The acid half is reduced all the way to a primary alcohol and the alcohol half is released as it was, so $CH_3CH_2CH_2COOCH_2CH_3$ gives butan-1-ol and ethanol. D is tempting because the aldehyde is a real step along the way, but $LiAlH_4$ does not stop there and reduces it to the alcohol.

43. Which of the following combinations does NOT form a buffer solution? (1)
- A. NH_3/HCl in 2:1 mole ratio
B. ✓ HNO_3/KNO_3 in 1:1 mole ratio
C. N_2H_4/N_2H_5Cl
D. $HCOOH/HCOOK$

Answer: B

A buffer needs a weak acid with its conjugate base, or a weak base with its conjugate acid. Nitric acid is strong, so it ionizes completely and KNO_3 brings nothing that can take up added acid, which leaves no buffering pair. A is the tempting wrong pick because it also contains a strong acid, but there the HCl only converts half the ammonia, leaving an NH_3 and NH_4^+ pair that does buffer.

44. Which substance is the reducing agent in the following reaction? $4\text{H}^+(\text{aq}) + 2\text{Cl}^-(\text{aq}) + \text{MnO}_2(\text{s}) \rightarrow \text{Cl}_2(\text{g}) + \text{Mn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ (1)
- A. $\text{H}^+(\text{aq})$ B. ✓ $\text{Cl}^-(\text{aq})$
C. $\text{Cl}_2(\text{g})$ D. $\text{MnO}_2(\text{s})$

Answer: B

The reducing agent is the species that is itself oxidized. Chlorine starts at -1 in Cl^- and finishes at 0 in Cl_2 , so it lost electrons and handed them to something else. D is tempting because MnO_2 drives the reaction, but manganese falls from $+4$ to $+2$, which means it gained electrons and acted as the oxidizing agent.

45. Which one of the following statements is not true regarding the electrolysis of concentrated sodium chloride solution? (1)
- A. Chlorine gas is produced at the anode.
B. ✓ **Oxygen gas is produced at the anode.**
C. Hydrogen gas is formed at the cathode.
D. After the electrolysis, the remaining solution becomes basic.

Answer: B

In concentrated brine the chloride ions are plentiful and they discharge at the anode, so chlorine gas is what comes off there. Water is reduced at the cathode to hydrogen, and the OH^- left behind with the sodium ions makes the remaining solution basic. Oxygen at the anode is what you would see with very dilute sodium chloride, which is why statement B reads plausibly but is false for concentrated brine.

46. The volume of O_2 formed at STP when Na_2SO_4 is electrolyzed by passing 100A in 965 seconds? (1)
- A. 9.6 L B. 22.4 L
C. ✓ **5.6 L** D. 0.25 L

Answer: C

Charge passed = $I \times t = 100 \times 965 = 96500\text{ C}$, which is exactly one mole of electrons. Sodium and sulfate are not discharged, so water reacts at the anode: $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^-$. Four moles of electrons give one mole of O_2 , so one mole gives 0.25 mol , and at STP that is $0.25 \times 22.4 = 5.6\text{ L}$. B is tempting because 22.4 L is the molar volume, but that would need four times as much charge.

47. If the reaction proceeds spontaneously, which of the following sets of conditions is satisfied? (1)
- A. $\Delta G^\circ < 0$, $K < 1$, $E^\circ < 0$ B. $\Delta G^\circ > 0$, $K > 1$, $E^\circ < 0$
C. ✓ **$\Delta G^\circ < 0$, $K > 1$, $E^\circ > 0$** D. $\Delta G^\circ > 0$, $K < 1$, $E^\circ < 0$

Answer: C

The three conditions move together. A spontaneous reaction has $\Delta G^\circ < 0$; since $\Delta G^\circ = -RT \ln K$, a negative ΔG° forces $K > 1$; and since $\Delta G^\circ = -nFE^\circ$, it also forces $E^\circ > 0$. A is tempting because it opens correctly with $\Delta G^\circ < 0$, but it then pairs that with $K < 1$ and $E^\circ < 0$, which those same two equations rule out.

48. Which one of the following is not true about electroplating of a tray made of iron with chromium? (1)
- A. Chromium metal placed in the anode
 - B. A tray made of iron placed in the cathode
 - C. ✓ **Use iron salt solution as an electrolyte**
 - D. Use chromium salt solution as an electrolyte

Answer: C

In electroplating the metal being deposited has to be present in the bath as ions, so plating chromium needs a chromium salt solution. The chromium bar is the anode and dissolves to replace what is used, the iron tray is the cathode where chromium is deposited, and those statements are all true. Using an iron salt solution would deposit iron onto iron, which is why C is the untrue statement the question is looking for.

49. Two cells are connected in series. One contains AgNO_3 and the other contains CuSO_4 . If 8g of Cu is deposited at one electrode, how many grams of Ag is deposited at the other electrode? (molar mass Ag=108 g/mol, Cu=64 g/mol) (1)
- A. 4
 - B. 14
 - C. ✓ **27**
 - D. 54

Answer: C

Cells in series pass the same charge. 8 g of copper is $8/64 = 0.125$ mol, and $\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}$ means that took 0.25 mol of electrons. Silver deposits as $\text{Ag}^+ + e^- \rightarrow \text{Ag}$, one electron per atom, so 0.25 mol of silver forms and its mass is $0.25 \times 108 = 27$ g. B is tempting if you give silver two electrons as well, which would halve the amount to about 14 g.

50. Which industrial chemicals mismatched with its manufacturing process? (1)
- A. NH_3 - Haber-Bosch process
 - B. HNO_3 - Ostwald process
 - C. H_2SO_4 - Contact process
 - D. ✓ **Na_2CO_3 - Frasch process**

Answer: D

Sodium carbonate is made by the Solvay process, from brine, limestone and ammonia. The Frasch process is a mining method: superheated water is pumped underground to melt sulfur and push it to the surface, so it has nothing to do with soda ash. C is tempting because sulfur turns up in both, but sulfuric acid really is made by the contact process, so that pair is correctly matched.

51. Among the following nitrogen-based fertilizers which is a high percentage nitrogen content? (1)
- A. ✓ **Anhydrous ammonia**
 - B. Urea-ammonium nitrate (UAN) solutions
 - C. Urea
 - D. DAP

Answer: A

Compare the nitrogen by mass in each fertilizer. Anhydrous ammonia is NH_3 , so nitrogen is 14/17, about 82%. Urea comes in near 46%, UAN solutions near 28 to 32%, and DAP near 18%. C is tempting because urea is the fertilizer farmers handle most, but ammonia carries almost twice as much nitrogen for the same weight.

52. All of the following undergoes addition polymerization except (1)
- A. Polyvinyl chloride (PVC)
 - B. Teflon
 - C. ✓ **Nylon**
 - D. Polystyrene

Answer: C

In addition polymerization monomers with a double bond open up and join, and nothing is lost. PVC, Teflon and polystyrene all form that way from vinyl type monomers. Nylon is different: a diamine and a diacid join and a small molecule of water leaves at each link, which makes it a condensation polymer. B is tempting because Teflon looks unusual, but its monomer C_2F_4 still carries the double bond that addition needs.

53. The correct order of preparatory stages in the tanning processes of animal hide or skin? (1)
- A. Soaking → scudding → flesh removal → hair removal → deliming → curing
 - B. Scudding → soaking → flesh removal → hair removal → curing → deliming
 - C. Deliming → flesh removal → hair removal → soaking → scudding → curing
 - D. ✓ **Curing → soaking → flesh removal → hair removal → scudding → deliming**

Answer: D

A hide starts to rot as soon as it leaves the animal, so curing preserves it before anything else happens. After that it is soaked to take up water again, the flesh is scraped off, the hair is removed, scudding cleans out what is left in the pores, and deliming prepares the hide for tanning. A is tempting because soaking feels like the natural first step, but an uncured hide would spoil on the way to the tannery.

54. What substance is used to bleach the brown syrup in the process of sugar manufacturing? (1)
- A. Potassium chlorate
 - B. ✓ **Sulfur dioxide**
 - C. Calcium chloride
 - D. Sodium hypochlorite

Answer: B

Sulfur dioxide is bubbled through the cane juice during clarification. It bleaches the brown colouring matter and also stops the syrup darkening again as it is boiled, so the sugar crystallises out white. D is tempting because sodium hypochlorite is a familiar household bleach, but it would leave chlorine residues in something people eat.

55. Which one of the following is a thermosetting plastic? (1)
- A. ✓ **Bakelite**
 - B. Polyethylene
 - C. Dacron
 - D. Polyvinyl chloride

Answer: A

A thermosetting plastic hardens once and cannot be melted and reshaped, because its chains are joined by cross links into a single rigid network. Bakelite, made from phenol and formaldehyde, is built that way. B is tempting, but polyethylene is a mass of long separate chains with no cross links, so it softens on heating and can be moulded again, which makes it a thermoplastic.

56. Any discharge of a solid, liquid or gaseous substance or radiation (energy) into an environment that causes unwanted changes is said to be: (1)
- A. ✓ **Pollution**
 - B. Corrosion
 - C. Contaminates
 - D. Slug

Answer: A

Pollution is the release of any solid, liquid, gas or energy into the environment in a form or amount that causes unwanted change. That is what the sentence describes. C is tempting because a contaminant is closely related, but a contaminant is the substance itself, while the question describes the act of discharging it and the harm that follows.

57. The component of the environment consisting earth's upper outermost skin and accessible to human beings is known as _____. (1)
- A. Atmosphere
 - B. Hydrosphere
 - C. ✓ **Lithosphere**
 - D. Biosphere

Answer: C

The lithosphere is the solid outer shell of the earth, the crust and the rock beneath it. It is the layer people dig, farm and build on, which is what the phrase about being accessible to human beings points at. D is tempting, but the biosphere is the zone where living things are found, and that cuts across land, water and air rather than being the outer skin of the earth.

58. Which of the following is not a greenhouse gas?

(1)

- A. Carbon dioxide (CO₂)
- B. Nitrogen dioxide (NO₂)
- C. Water vapor (H₂O)
- D. ✓ Oxygen (O₂)

Answer: D

To be a greenhouse gas a molecule must absorb infrared radiation, and it can only do that if its vibration changes the way charge is spread inside it. Oxygen is two identical atoms, so stretching it changes no dipole and infrared passes straight through. B is tempting because nitrogen dioxide is a serious air pollutant, but being harmful to breathe and trapping heat are two different things.

59. Which principle of green chemistry focuses on eliminating waste rather than cleaning it up later?

(1)

- A. Atom Economy
- B. ✓ Prevention
- C. Design for Energy Efficiency
- D. Safer Solvents and Auxiliaries

Answer: B

The first principle of green chemistry is prevention: it is better to design a process that makes no waste than to treat or clean up waste afterwards. A is tempting because atom economy also cuts waste, but it does so by designing the reaction so that more of the starting mass ends up in the product, which is a different principle with a different test.

60. Which principle emphasizes maximizing the desired product and minimizing by-products?

(1)

- A. Design for energy efficiency
- B. Use of renewable feedstock
- C. Less hazardous chemical synthesis
- D. ✓ Atom economy

Answer: D

Atom economy asks how much of the mass of the reactants finishes up in the wanted product. A high atom economy means most atoms end up in the product and few are thrown away as by-products, which is exactly what the question describes. C is tempting, but less hazardous synthesis is about how harmful the substances used and made are, not about how much of them reaches the product.

61. Identify the correct statement about metallic conductivity and electrolytic conductivity.

(1)

- A. ✓ **Metallic conductivity decreases while electrolytic conductivity increases with increasing temperature**
- B. Both conductivities increase with increasing temperature
- C. Both conductivities decrease with increasing temperature
- D. Metallic conductivity increases while electrolytic conductivity decreases with increasing temperature

Answer: A

Metals conduct through free electrons. Heating makes the metal ions vibrate harder, the electrons are scattered more often, and the conductivity falls. An electrolyte conducts through ions moving in solution, and heating lowers the viscosity and speeds the ions up, so its conductivity rises. D is tempting if you assume both kinds of conduction react to heat the same way, but the charge carriers are different and so are the effects.

62. Equal energy of orbitals (degenerate orbitals) are each occupied by a single electron before the second electron of opposite spin enters the orbital. This principle is

(1)

- A. Avogadro's principle
- B. Aufbau principle
- C. Pauli's exclusion principle
- D. ✓ Hund's principle

Answer: D

Hund's principle says that when orbitals have the same energy, electrons occupy them one at a time with parallel spins before any orbital takes a second electron. Spreading out this way keeps the electrons apart and lowers the repulsion between them. B is tempting because the aufbau principle also describes filling, but that one sets the order in which subshells are filled by energy, not how electrons share a set of orbitals that are equal in energy.

63. Which of the following is true about homologous series? The Homologous series is? (1)
- A. The existence of chemical compounds that have the same molecular formula but different in structural formation
 - B. A structure in which the isomers have different functional group with respect to the double bond
 - C. The property of an element to form chains with the repetition of the same atom
 - D. ✓ **A group of molecules each differing from the next member by a certain group**

Answer: D

A homologous series is a family of compounds built on one general formula, where each member differs from the next by a CH_2 unit. The alkanes are the standard example, and that steady step is why their properties change gradually down the series. A is tempting, but compounds with the same molecular formula and different arrangements are isomers, which is a different idea.

64. Which one of the following is not amphiprotic? (1)
- A. HS^-
 - B. ✓ **NH_4^+**
 - C. H_2O
 - D. HCO_3^-

Answer: B

Amphiprotic means a species can both give a proton away and take one up. HS^- , H_2O and HCO_3^- each carry a hydrogen they can release and a lone pair they can use to accept one. NH_4^+ can give a proton, but nitrogen has no lone pair left in it and the ion is already positive, so it cannot accept another. D is tempting because HCO_3^- is often met as an acid, but it turns into H_2CO_3 when it accepts a proton, so it works both ways.

65. A solution of H_2SO_4 is made by dissolving 245g of the acid in enough water to produce 500ml solution. What is the normality of the solution? (At. Wt. H=1, S=32, O=16) (1)
- A. 2
 - B. 4
 - C. 8
 - D. ✓ **10**

Answer: D

The molar mass of H_2SO_4 is $2 \times 1 + 32 + 4 \times 16 = 98$ g/mol, so $245/98 = 2.5$ mol. In 0.5 L that is $2.5/0.5 = 5$ mol/L. Normality counts the protons an acid can supply, and sulfuric acid supplies two, so $N = 2 \times 5 = 10$. A is tempting if you divide 245 by 98 and stop there, but 2.5 mol is an amount of acid, not a concentration, and the two protons still have to be counted.

END OF THE MARKING KEY

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