DPP – 9
CONDUCTANCE (Part 2)

Chapter: Electrochemistry • Complete Solutions

"Do this assignment not for me, not for marks — but for your own growth."

Quick Answer Key

1. (3) 2. (2) 5. (2) 6. (1) 9. (4) 10. (4) 13. (1) 14. (1) 17. (1)
3. (3) 4. (2) 7. (2) 8. (3) 11. (1) 12. (4) 15. (2) 16. (2)

TYPE–1 : Basic Concepts of Electrolytic Conduction

1. Strong electrolytes are those which:

Explanation

Strong electrolytes dissociate *completely* into ions in aqueous solution, and they remain dissociated **even at high concentration**. They do not wait for dilution to ionise—they are fully ionised from the moment they dissolve.

- Option (1): Solubility is a separate property from being a strong electrolyte.
- Option (2): Both strong *and* weak electrolytes conduct electricity; this is not distinguishing.
- **Option (3): Correct.** Strong electrolytes are fully dissociated at all concentrations, including high concentration.
- Option (4): This describes *weak* electrolytes—they show significant dissociation only upon high dilution.

Approach & Analogy

Analogy: Think of strong electrolytes as a *firecracker that always bursts*—no matter how many you pack together (high concentration), each one still explodes (dissociates) completely. A weak electrolyte is like a damp sparkler—it only sparks properly when given enough room (dilution).

Answer

Option (3) — Strong electrolytes dissociate into ions **even at high concentration**.

2. Molten sodium chloride conducts electricity due to the presence of:

Explanation

In the solid state, NaCl has ions fixed in a crystal lattice—they cannot move, so no conduction. On melting, the lattice breaks down and **free ions** (Na^+ and Cl^-) become mobile.

- Option (1): Free electrons are responsible for *metallic* conduction, not electrolytic.
- **Option (2): Correct.** Free Na^+ and Cl^- ions carry charge through the melt.
- Options (3) & (4): Ionic compounds do not exist as neutral molecules or free atoms.

Approach & Analogy

Analogy: Solid NaCl is like people locked in stadium seats—they cannot move. Molten NaCl opens all the gates—the ions (people) are finally free to walk around (carry charge). Electrons are for metals (like a moving walkway inside the stadium floor), not for ionic melts.

Answer

Option (2) — Molten NaCl conducts via **free ions** (Na^+ and Cl^-).

3. Electrolytic conduction is due to the movement of:

Explanation

This is definitional. In electrolytic conduction, charge is carried by **ions**—cations move towards the cathode and anions towards the anode. Electrons carry charge only in metals (metallic conduction). Molecules and atoms are electrically neutral and carry no charge.

Approach & Analogy

Analogy: In a swimming relay race, the baton (charge) is carried by the *swimmers* (ions). In a wire (metallic conductor), the baton is carried by tiny invisible runners—the electrons. Two different carriers, two different types of conduction.

Answer

Option (3) — Electrolytic conduction is due to the movement of **ions**.

4. Electrolytic conduction differs from metallic conduction in that in the former:

Explanation

The key difference relates to how **temperature** affects resistance:

Property	**Metallic Conductor**	**Electrolytic Conductor**
Charge carrier	Electrons	Ions
Effect of $\uparrow T$	Resistance **increases**	Resistance **decreases**
Reason	More lattice vibrations	More ionic mobility, more dissociation

Option (2) correctly states: In electrolytic conductors, resistance *decreases* with increasing temperature (conductance increases). This is the distinguishing fact asked here.

Approach & Analogy

Analogy: In a metal wire, heating causes the crystal lattice to vibrate more—like bumpy roads slowing down cars (electrons). More heat = worse road = higher resistance.

In a salt solution, heating gives ions more kinetic energy and reduces viscosity—like clearing traffic jams on the highway. More heat = smoother flow = lower resistance.

Answer

Option (2) — In electrolytic conductors, **resistance decreases with increasing temperature**.

TYPE–2 : Conductance Behaviour with Dilution

Key Concept: Effect of Dilution

Property	**On Dilution**	**Reason**
Specific conductance (κ)	Decreases	Fewer ions per unit volume
Molar/Equiv. conductance (Λ)	Increases	Higher ionic mobility; more dissociation
Conductance (G) of solution	Increases	More ions overall (for weak electrolytes)

5. Which statement is not correct:

Explanation

The question asks for the **incorrect** statement. Evaluating each:

- Option (1): Conductance (G) of solution *increases* on dilution for strong electrolytes (more total ions become available). **TRUE.**
- Option (2): This says conductance *decreases* on dilution. This is **WRONG** for electrolytic solutions—conductance increases on dilution. **This is the incorrect statement.**
- Option (3): Specific conductance (κ) *decreases* on dilution—correct, because ion density per unit volume drops. **TRUE.**
- Option (4): Equivalent conductance increases on dilution—correct. **TRUE.**

Approach & Analogy

Memory trick: *Specific* conductance is like *concentration*—both decrease on dilution. *Molar/Equivalent* conductance is a *per-mole* property—it improves as ions get more freedom (less interaction) on dilution.

Answer

Option (2) is the incorrect statement — Conductance of an electrolytic solution **increases** (not decreases) with dilution.

6. Which one of the following is wrong:

Explanation

Again we look for the **wrong** statement:

- Option (1): Specific conductance *increases* on dilution—**WRONG.** Specific conductance *decreases* on dilution because the number of ions per unit volume falls.
- Option (2): Specific conductance *decreases* on dilution—**Correct.**
- Option (3): Equivalent conductance increases on dilution—**Correct.**
- Option (4): Molar conductance increases on dilution—**Correct.**

Approach & Analogy

Analogy: Specific conductance is like the *flavour strength* of a tea. As you add more water (dilute), the flavour weakens—fewer flavour molecules (ions) per sip (unit volume). But each individual flavour molecule (ion) is *freer* to move—hence molar conductance rises.

Answer

Option (1) is wrong — Specific conductance **decreases** (not increases) on dilution.

7. An increase in equivalent conductance of a strong electrolyte with dilution is mainly due to:

Explanation

For a **strong electrolyte**, 100% ionisation already exists at normal concentration. So the increase in Λ_{eq} on dilution is **not** due to more ions being produced.
The main reason is: **increase in ionic mobility**. On dilution:

- Inter-ionic attractions decrease (less electrostatic drag).
- Viscosity decreases.
- Ions can move faster under the applied electric field.

This is described by Kohlrausch's law: $\Lambda_{eq} = \Lambda^\circ_{eq} - K\sqrt{C}$ —as C decreases, Λ_{eq} rises towards Λ°.

Approach & Analogy

Analogy: Strong electrolyte ions are like runners already on the track. On dilution, we remove crowd barriers (reduce inter-ionic attraction)—the runners don't multiply, but they run *faster*. This is purely a mobility (speed) improvement, not a number improvement.

Answer

Option (2) — Increase in **ionic mobility** of ions (not increase in number of ions).

8. Which of the following is not correct?

Explanation

- Option (1): Molar conductance increases with dilution—**Correct.**
- Option (2): Equivalent conductance increases with dilution—**Correct.**
- Option (3): Specific conductance increases with dilution—**WRONG.** Specific conductance (κ) decreases on dilution.
- Option (4): At infinite dilution each ion contributes independently—this is Kohlrausch's law of independent migration: $\Lambda^\circ_m = \lambda^\circ_+ + \lambda^\circ_-$. **Correct.**

Answer

Option (3) is not correct — Specific conductance **decreases** (not increases) with dilution.

9. Equivalent conductance of a substance increases on dilution because of:

Explanation

For **weak electrolytes**: Λ_{eq} increases on dilution primarily due to **increase in degree of ionisation**. More dissociation occurs as the solution becomes dilute, producing more ions that can carry charge.
For strong electrolytes, it is ionic mobility. But this question is general—the classic textbook answer for *why* Λ_{eq} increases is "increase in degree of ionisation."
Evaluating options:

- Option (1): Ions per unit volume actually *decreases* on dilution (specific conductance falls)—wrong.
- Option (2): Molecular attraction has no role here—wrong.
- Option (3): Degree of *association* would decrease conductance—wrong.
- **Option (4)**: Increase in degree of ionisation—**Correct.**

Approach & Analogy

Analogy (Weak Electrolyte): Think of CH_3COOH molecules as shy people in a crowded room. When the room empties (dilution), they feel less inhibited (less association pressure) and more of them speak up (ionise). More speakers = more ions = higher equivalent conductance.

Answer

Option (4) — Increase in **degree of ionisation** of the substance.

TYPE–3 : Factors Affecting Conductivity

10. Which of the following solutions of NaCl will have the highest specific conductance?

Explanation

Specific conductance (κ) depends on the **number of ions per unit volume**. More concentrated solution $\Rightarrow$ more ions per cm^3 $\Rightarrow$ higher κ.
Comparing concentrations: $1.0\,N > 0.1\,N > 0.01\,N > 0.001\,N$
Therefore κ is highest for the most concentrated solution: **1.0 N NaCl**.

Approach & Analogy

Analogy: Specific conductance is like the *traffic density* on a road. A concentrated solution is like rush hour—more cars (ions) per stretch of road. More cars = more traffic (current) per unit area = higher specific conductance.

Answer

Option (4) — **1.0 N NaCl** has the highest specific conductance (maximum ion density).

11. Which of the following solutions of KCl has the lowest value of equivalent conductance?

Explanation

By Kohlrausch's law:

$$\Lambda_{eq} = \Lambda^{\circ}_{eq} - K\sqrt{C}$$

Higher concentration $\Rightarrow$ more inter-ionic attractions $\Rightarrow$ lower ionic mobility $\Rightarrow$ **lower** Λ_{eq}.
Among 1 M, 0.1 M, 0.01 M, 0.001 M: the highest concentration is **1 M** $\Rightarrow$ lowest Λ_{eq}.

Approach & Analogy

Analogy: Equivalent conductance is like a runner's speed in a crowd. At 1 M (huge crowd), ions constantly bump into each other—slowest speed = lowest conductance. At 0.001 M (empty stadium), ions sprint freely = highest conductance.

Answer

Option (1) — **1 M KCl** has the lowest equivalent conductance.

12. Which of the following can change the conductivity of an electrolytic solution?

Explanation

All three factors affect conductivity:

- **Temperature**: Higher T increases ionic mobility (lower viscosity, less inter-ionic forces) $\Rightarrow$ increases κ.
- **Viscosity**: Higher viscosity resists ion movement $\Rightarrow$ decreases κ. Lower viscosity allows faster ion motion.
- **Interionic attraction**: Stronger attractions (higher concentration or higher charge) slow down ions $\Rightarrow$ decreases κ.

All three are interdependent and all affect conductivity.

Approach & Analogy

Analogy: Conductivity is like how fast parcels (ions) are delivered in a city. Temperature is like energy given to couriers (faster = more deliveries). Viscosity is like road congestion (thicker = slower). Interionic attraction is like couriers getting distracted by each other (pulling each other back). Any of these changes, delivery speed changes!

Answer

Option (4) — **All of these**: Temperature, viscosity, and interionic attraction all affect conductivity.

13. The value of specific conductivity is maximum for:

Explanation

Specific conductance (κ) increases with concentration (more ions per unit volume).
Comparing: $0.1\,\text{M} > 0.01\,\text{M} > 10^{-4}\,\text{M}$
The highest concentration is 0.1 M NaCl, so it has the **maximum** κ.

Answer

Option (1) — **0.1 M NaCl** has the maximum specific conductivity.

14. Limiting molar conductivity of which ion is maximum in water at 298 K?

Explanation

The limiting molar conductivities ($\lambda°$) at 298 K are:

Ion	$\lambda°$ (S cm^2 mol^{-1})
H^+	**349.8**
Na^+	50.1
K^+	73.5
Ca^{2+}	119.0

H^+ has by far the highest conductivity due to the **Grotthuss mechanism** (proton hopping): protons jump from one water molecule to the next without physically moving through the solution. This is orders of magnitude faster than ordinary ion migration.

Approach & Analogy

Analogy: Imagine a line of people passing a ball (proton) hand-to-hand. The ball travels the entire length instantly without any person walking. This is how H^+ "moves"—it's actually the *bond* that shifts along a chain of water molecules. Regular ions (Na^+, K^+) must physically push through the liquid, which is much slower.

Answer

Option (1) — H^+ has the **maximum limiting molar conductivity** due to the Grotthuss proton-hopping mechanism. $\lambda°(H^+) = 349.8\,\text{S cm}^2\,\text{mol}^{-1}$.

15. The molar conductivity of HCl is greater than that of NaCl because:

Explanation

Both HCl and NaCl are strong electrolytes—100% ionised. So ionisation is *not* the reason.
By Kohlrausch's law:

$$\Lambda_m^\circ(\text{HCl}) = \lambda^\circ(\text{H}^+) + \lambda^\circ(\text{Cl}^-)$$

$$\Lambda_m^\circ(\text{NaCl}) = \lambda^\circ(\text{Na}^+) + \lambda^\circ(\text{Cl}^-)$$

Since $\lambda^\circ(H^+) = 349.8 \gg \lambda^\circ(Na^+) = 50.1$ S cm^2 mol^{-1}, the molar conductivity of HCl is much larger.
The Cl^- contributions are equal and cancel. The difference is entirely due to the **exceptional velocity of H^+ ions** (Grotthuss mechanism).

Approach & Analogy

Think of it this way: In a relay race (HCl vs NaCl), the Cl^- runners are identical. But HCl fields H^+—the superstar runner who teleports the baton forward. NaCl fields Na^+ —a normal runner. HCl wins easily, not because of team size, but because of H^+'s extraordinary speed.

Answer

Option (2) — **Velocity of H^+ ions is more than that of Na^+ ions** (due to the Grotthuss proton-hopping mechanism).

16. The highest electrical conductivity among the following aqueous solutions is of:

Explanation

All are 0.1 M carboxylic acid solutions (weak electrolytes). Conductivity depends on the **degree of ionisation** (α), which increases with the **acid strength** (higher K_a).
Inductive effect of halogens on acetic acid:

- CH_3COOH: No electron-withdrawing group. Weakest acid. Lowest α.
- $ClCH_2COOH$ (chloroacetic acid): One Cl atom withdraws electron density, stabilising COO^-. Stronger than plain CH_3COOH.
- FCH_2COOH (fluoroacetic acid): One F atom. F is more electronegative than Cl but one substitution—moderate strength.
- $F_2CHCOOH$ (difluoroacetic acid): **Two F atoms** = stronger combined electron-withdrawing effect = most acidic among these options = highest α = highest conductivity.

Order of K_a: difluoroacetic > fluoroacetic > chloroacetic > acetic
Note: Trifluoroacetic (CF_3COOH) is even stronger, but not listed here.

Approach & Analogy

Analogy: The F atoms are like drain pipes pulling negative charge away from the COOH group—making it easier for H^+ to leave (ionise). Two drain pipes (difluoroacetic) drain faster than one (fluoroacetic), which drains faster than a less efficient one (Cl), which is better than no drain at all (plain acetic acid).

Answer

Option (2) — **0.1 M difluoroacetic acid** (CHF_2COOH) has the highest electrical conductivity due to the strongest combined inductive effect of two F atoms.

17. Which has maximum conductivity?

(1) $[Cr(NH_3)_6]Cl_3$ (2) $[Cr(NH_3)_5Cl]Cl_2$ (3) $[Cr(NH_3)_4Cl_2]Cl$ (4) $[Cr(NH_3)_3Cl_3]$

Explanation

Conductivity of coordination compounds depends on the **number of free ions** released in solution. More free ions ⇒ higher conductivity.

Option	Complex	Ions released	Type
(1)	$[Cr(NH_3)_6]Cl_3$	$[Cr(NH_3)_6]^{3+} + 3\,Cl^-$	**4 ions**
(2)	$[Cr(NH_3)_5Cl]Cl_2$	$[Cr(NH_3)_5Cl]^{2+} + 2\,Cl^-$	3 ions
(3)	$[Cr(NH_3)_4Cl_2]Cl$	$[Cr(NH_3)_4Cl_2]^{+} + 1\,Cl^-$	2 ions
(4)	$[Cr(NH_3)_3Cl_3]$	No ions	0 free ions

The complex with the most ions in solution (**4 ions from option 1**) conducts most. Note: Cl inside the coordination sphere (square brackets) does *not* ionise; only the outer-sphere Cl^- ions are free.

Approach & Analogy

Analogy: Think of the complex ion as a bus, and the outer Cl^- ions as passengers who got off at the bus stop (ionised). Option (1) has 3 passengers off the bus + the bus itself = 4 moving entities. Option (4)'s bus has no passengers getting off—no free ions, no conductance. More passengers roaming freely = more charge carriers = higher conductivity.

Answer

Option (1) — $[Cr(NH_3)_6]Cl_3$ has the **maximum conductivity** as it releases **4 ions** in solution: $[Cr(NH_3)_6]^{3+}$ and $3\,Cl^-$.

Key Concepts to Remember — DPP 9

Concept	**Key Point**
Strong electrolyte	Fully dissociated *even at high concentration*
Metallic vs. electrolytic	Metal: R increases with T; Electrolyte: R decreases with T
κ on dilution	Decreases (fewer ions per unit volume)
Λ_m, Λ_{eq} on dilution	Increases (more ionic mobility / more ionisation)
Strong electrolyte Λ_{eq} increase	Due to ionic mobility (not number of ions)
Highest λ° ion	H^+ (Grotthuss mechanism; $349.8\,S\,cm^2\,mol^{-1}$)
HCl vs NaCl conductance	H^+ faster than Na^+; not due to ionisation difference
Coordination complex conductance	More outer-sphere ions ⇒ higher conductivity