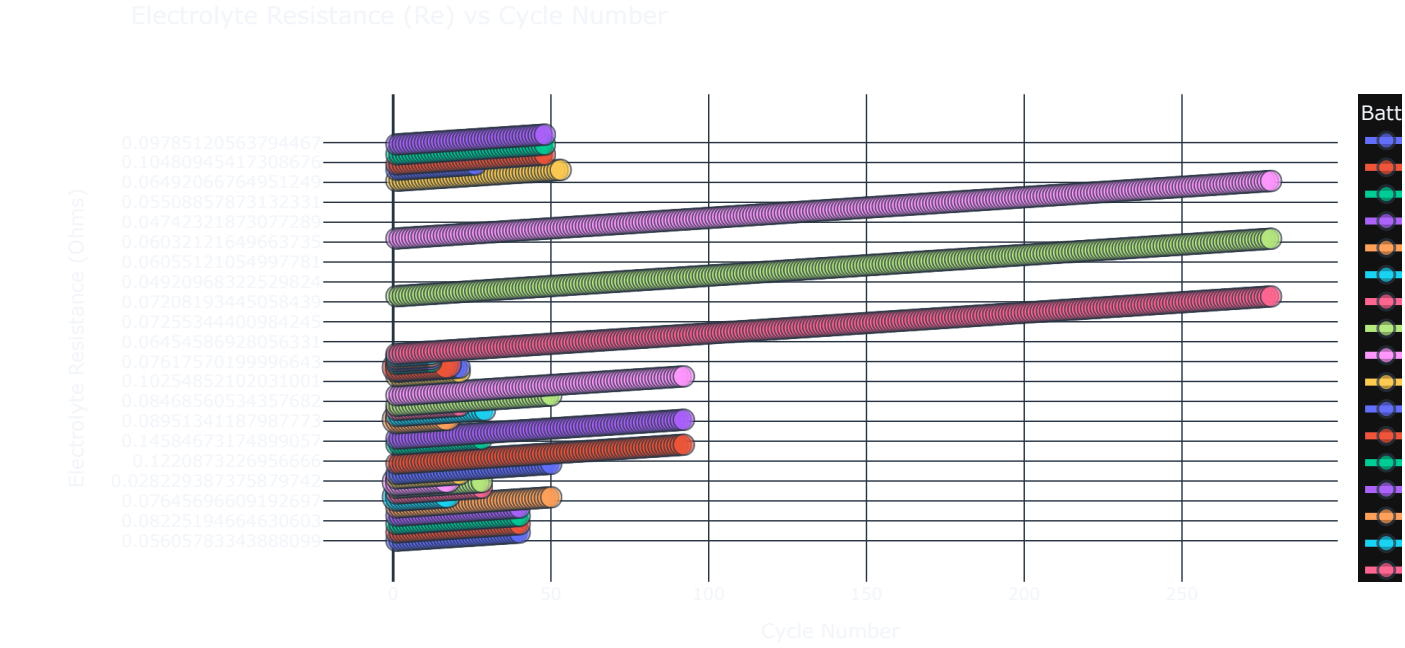
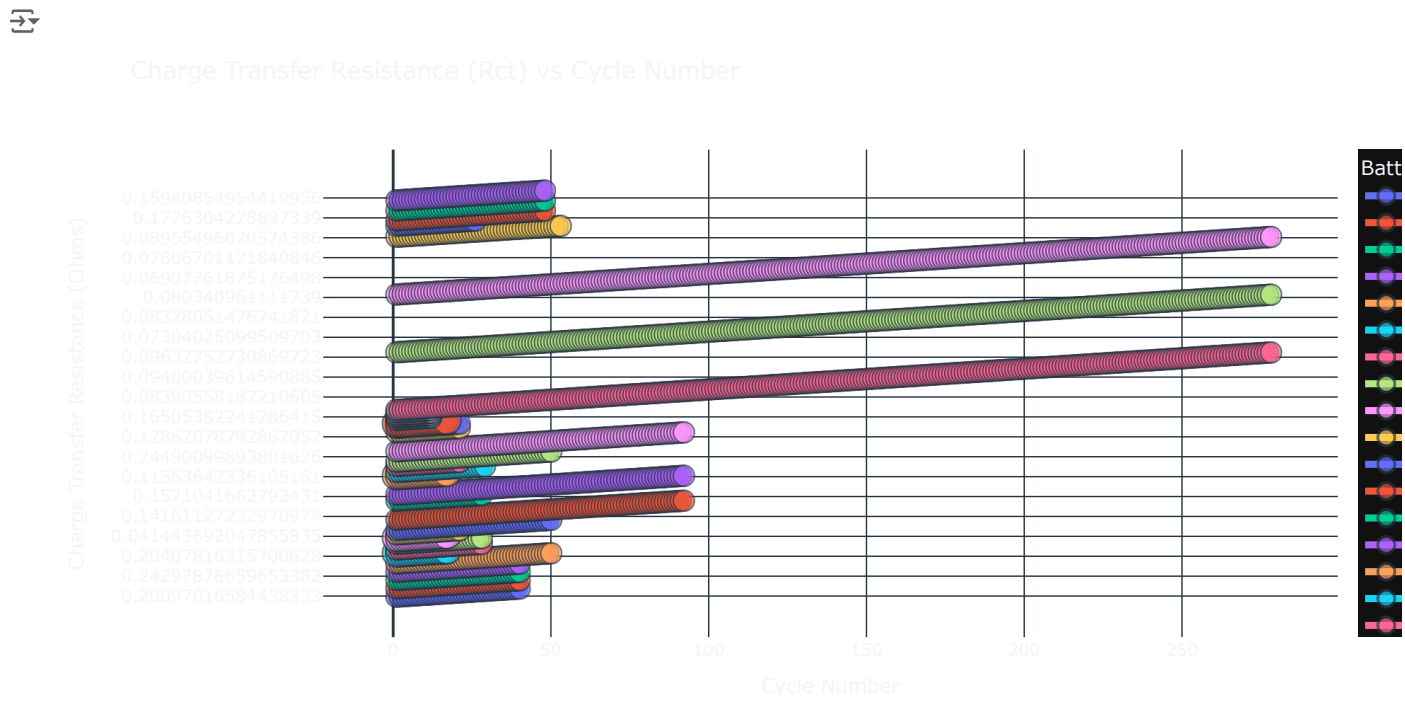
```
import pandas as pd
import plotly.express as px
import plotly.graph_objects as go



# Load dataset
file_path = 'metadata.csv'
data = pd.read_csv(file_path)

# Filter relevant data for "impedance" rows
impedance_data = data[data['type'] == 'impedance'].copy()

# Add cycle numbers for each battery
impedance_data['Cycle_Number'] = impedance_data.groupby('battery_id').cumcount() + 1

# Drop rows with missing values for Re and Rct
non_missing_data = impedance_data[['battery_id', 'Cycle_Number', 'Re', 'Rct', 'ambient_temperature']].dropna()



'''
# Summary of Observations
print("Summary of Observations:")
print(non_missing_data.groupby('battery_id')[['Re', 'Rct']].describe())

# Focus on Top 5 Batteries
top_batteries = non_missing_data['battery_id'].value_counts().head(5).index
filtered_data = non_missing_data[non_missing_data['battery_id'].isin(top_batteries)]
'''


# ---- Plot 1: Re (Electrolyte Resistance) vs Cycle Number ----
fig_re = px.scatter(
    non_missing_data,
    x='Cycle_Number',
    y='Re',
    color='battery_id',
    size='ambient_temperature',
    title='Electrolyte Resistance (Re) vs Cycle Number',
    labels={'Cycle_Number': 'Cycle Number', 'Re': 'Electrolyte Resistance (Ohms)', 'battery_id': 'Battery ID'},
    hover_data=['ambient_temperature'],
    template='plotly_dark'
)
fig_re.update_traces(mode='markers+lines')
fig_re.show()
```

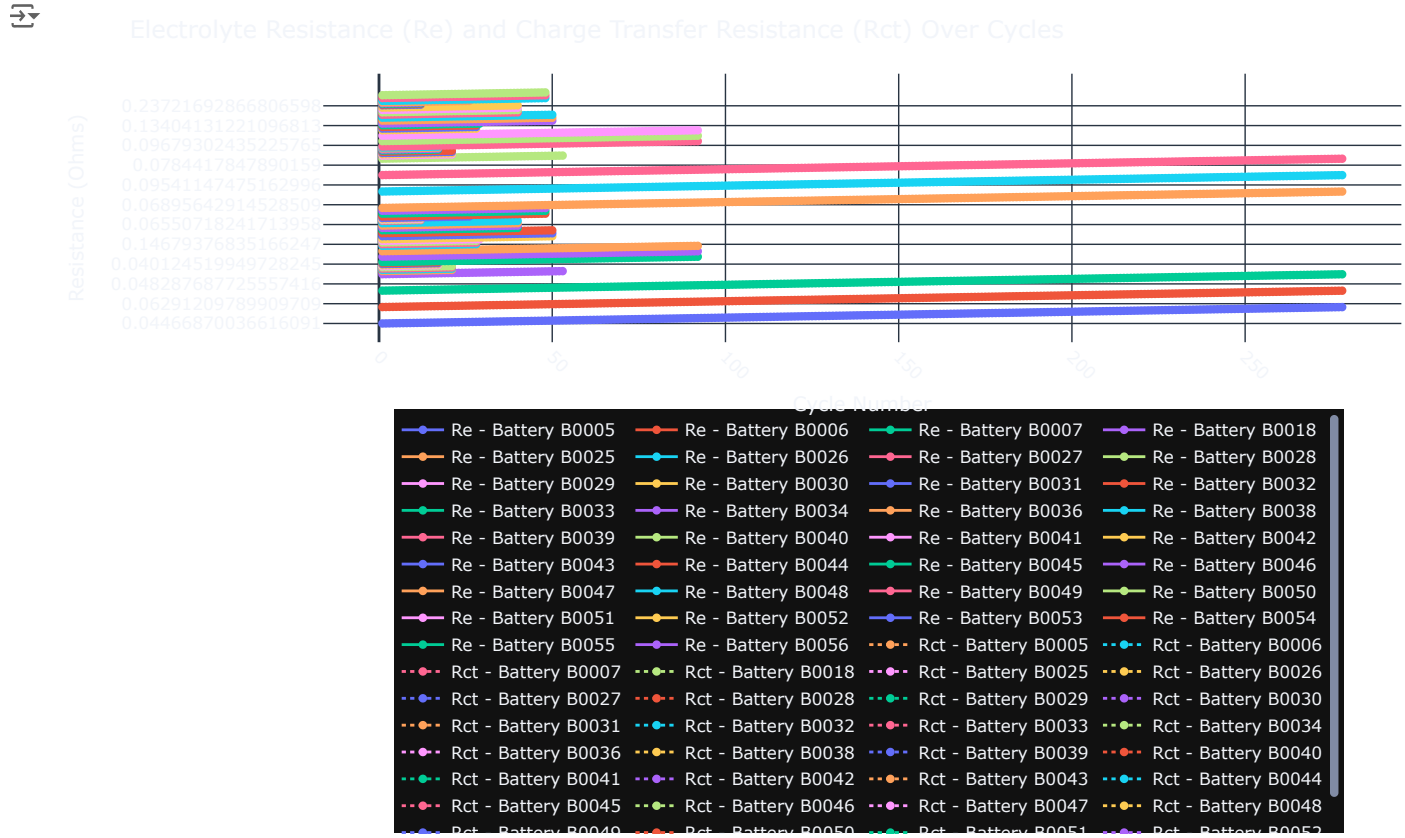


```
# ---- Plot 2: Rct (Charge Transfer Resistance) vs Cycle Number ----
fig_rct = px.scatter(
    non_missing_data,
    x='Cycle_Number',
    y='Rct',
    color='battery_id',
    size='ambient_temperature',
    title='Charge Transfer Resistance (Rct) vs Cycle Number',
    labels={'Cycle_Number': 'Cycle Number', 'Rct': 'Charge Transfer Resistance (Ohms)', 'battery_id': 'Battery ID'},
    hover_data=['ambient_temperature'],
    template='plotly_dark'
)
fig_rct.update_traces(mode='markers+lines')
fig_rct.show()
```

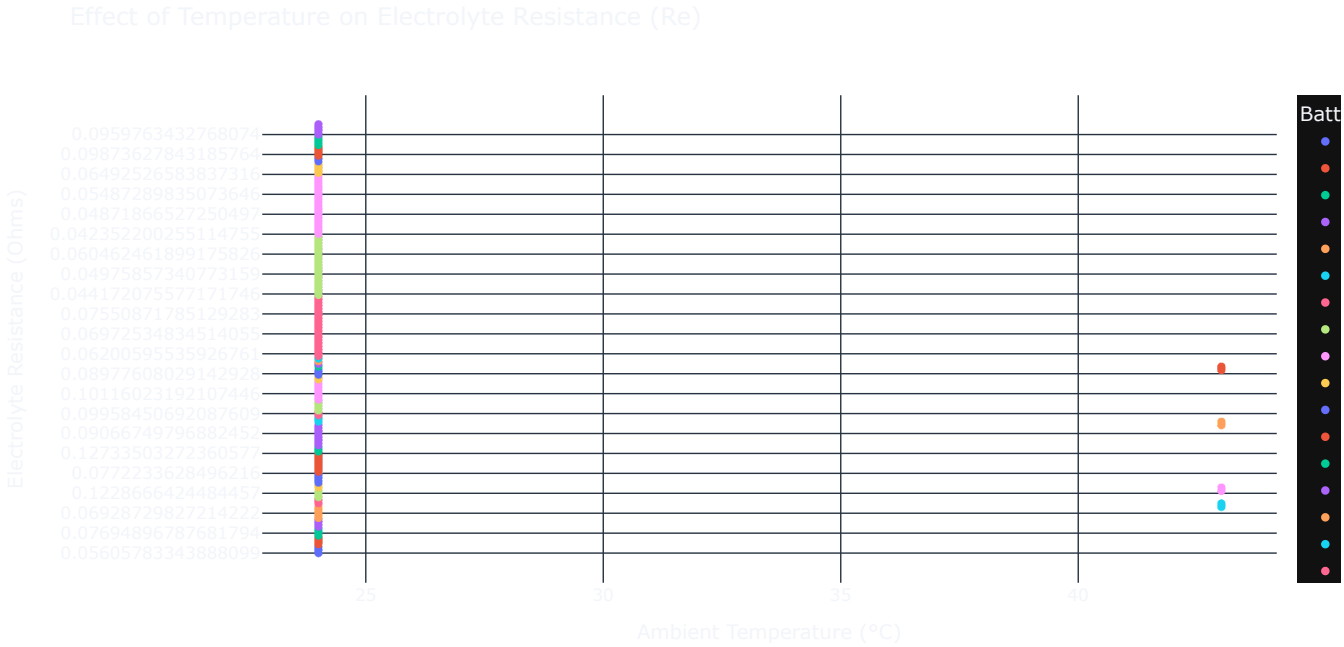


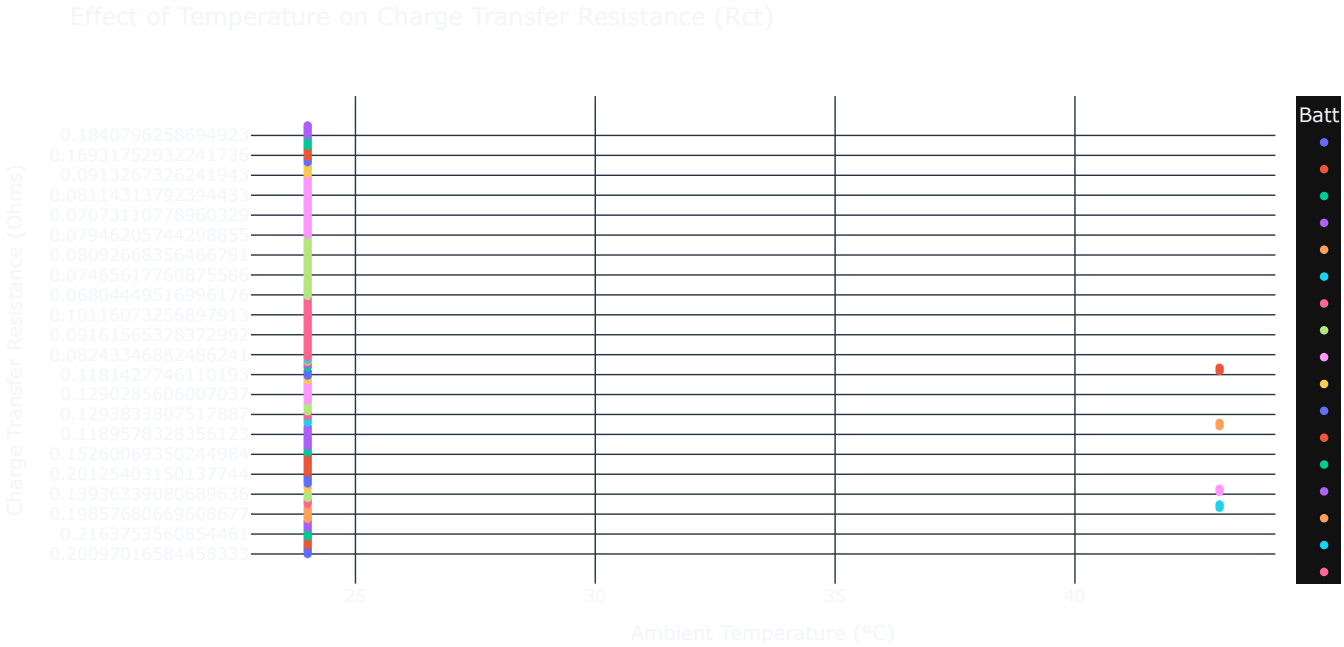

```
# ---- Combined Insights Plot: Re and Rct Over Cycles ----
fig_combined = go.Figure()

for battery_id, group in non_missing_data.groupby('battery_id'):
    fig_combined.add_trace(go.Scatter(
        x=group['Cycle_Number'], y=group['Re'],
        mode='lines+markers',
        name=f'Re - Battery {battery_id}',
        line=dict(shape='spline'),
        hoverinfo='x+y+name'
    ))

# Add Rct for each battery
for battery_id, group in non_missing_data.groupby('battery_id'):
    fig_combined.add_trace(go.Scatter(
        x=group['Cycle_Number'], y=group['Rct'],
        mode='lines+markers',
        name=f'Rct - Battery {battery_id}',
        line=dict(shape='spline', dash='dot'),
        hoverinfo='x+y+name'
    ))


fig_combined.update_layout(
    title='Electrolyte Resistance (Re) and Charge Transfer Resistance (Rct) Over Cycles',
    xaxis_title='Cycle Number',
    yaxis_title='Resistance (Ohms)',
    template='plotly_dark',
    legend=dict(
        orientation='h',
        x=0.5,
```

```
        xanchor='center',
        y=-0.25
    ),
    margin=dict(t=50, b=120, l=50, r=50),
    xaxis=dict(
        title=dict(standoff=10),
        tickangle=45
    ),
    height=600,
    width=1000
)
```




```
# ---- Additional Analysis: Temperature Effect on Resistance ----
fig_temp_re = px.scatter(
    non_missing_data,
    x='ambient_temperature',
    y='Re',
    color='battery_id',
    title='Effect of Temperature on Electrolyte Resistance (Re)',
    labels={'ambient_temperature': 'Ambient Temperature (°C)', 'Re': 'Electrolyte Resistance (Ohms)', 'battery_id': '
    template='plotly_dark'
)
fig_temp_re.show()

fig_temp_rct = px.scatter(
    non_missing_data,
    x='ambient_temperature',
    y='Rct',
    color='battery_id',
    title='Effect of Temperature on Charge Transfer Resistance (Rct)',
    labels={'ambient_temperature': 'Ambient Temperature (°C)', 'Rct': 'Charge Transfer Resistance (Ohms)', 'battery_i
    template='plotly_dark'
)
fig_temp_rct.show()
```


Effect of Temperature on Electrolyte Resistance (Re)
Electrolyte Resistance (Ohms)
Ambient Temperature (°C)
Batt


Effect of Temperature on Charge Transfer Resistance (Rct)
Charge Transfer Resistance (Ohms)
Ambient Temperature (°C)
Batt