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Solubility and Compatibility Analysis of Nitrile Butadiene Rubber (NBR) of Varying ACN Content in Selected Solvents

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Abstract
The solubility and compatibility of nitrile butadiene rubber (NBR) with varying acrylonitrile (ACN) content were investigated in a series of solvents with different polarity characteristics. NBR grades containing 18%, 28.3%, 33.15%, and 38.15% ACN were studied in ethyl acetate, acetone, methyl ethyl ketone (MEK), hexane, and dimethyl sulfoxide (DMSO). Solubility tests revealed that NBR was soluble in ethyl acetate, acetone, and MEK, while remaining insoluble in hexane and DMSO. Differential scanning calorimetry (DSC) was employed to evaluate glass transition temperature (Tg), showing a strong dependence on both ACN content and solvent type. Results demonstrated that higher ACN content increases polarity-driven interactions, shifting Tg accordingly, with MEK imparting the strongest plasticization effect. The study provides a systematic framework for understanding solvent–NBR interactions, which is critical for adhesives, coatings, and rubber compounding industries.

1. Introduction

Nitrile butadiene rubber (NBR) is one of the most important polar synthetic rubbers, produced via the copolymerization of acrylonitrile (ACN) with butadiene. It is extensively used in seals, gaskets, fuel hoses, adhesives, and protective coatings due to its excellent oil and fuel resistance, thermal stability, and mechanical strength [1,2].

The ACN content in NBR typically ranges between 18–50 wt%, which determines its polarity and directly influences swelling, solubility, gas permeability, and glass transition behavior [3,4]. A higher ACN fraction improves resistance to oils, fuels, and nonpolar hydrocarbons but reduces flexibility and low-temperature resilience [5]. Conversely, low-ACN NBR exhibits superior elasticity and better cryogenic performance but poor chemical resistance [6]. This tunability makes ACN content a critical parameter in designing NBR-based materials for specific applications.

Solubility behavior of polymers is strongly governed by thermodynamic compatibility, which can be predicted through Hildebrand solubility parameters (δ) and Hansen solubility parameters (HSP) [7,8]. NBR, being moderately polar, is soluble in solvents such as ketones and esters, whereas highly polar solvents (e.g., DMSO) or nonpolar solvents (e.g., hexane) fail to dissolve the polymer efficiently [9,10]. Understanding solubility is vital for applications in adhesives, where solvent-assisted dissolution enables uniform coatings, and in polymer blending, where solvent selection governs miscibility [11].

Another key property is the glass transition temperature (Tg), which reflects chain segment mobility. Tg is sensitive to ACN content, with increasing polarity restricting chain flexibility and thus raising Tg [12]. Moreover, solvent interaction influences Tg through plasticization: solvents with good compatibility lower

Tg by enhancing free volume, while poor solvents may restrict chain movement or induce phase separation [13,14].

Previous studies have addressed the thermal and mechanical properties of NBR [15–18], but systematic investigation of solubility and Tg as a function of ACN content across multiple solvents remains limited. Such knowledge is essential for industries relying on solvent processing, such as paints, coatings, and adhesives.

Therefore, the present study investigates NBR grades with 18%, 28.3%, 33.15%, and 38.15% ACN content in ethyl acetate, acetone, MEK, hexane, and DMSO. Solubility was experimentally determined, and Tg was measured using DSC. Results are analysed in terms of polymer solvent interaction theory, with implications for practical applications in coatings, adhesives, and rubber processing.

2. Experimental

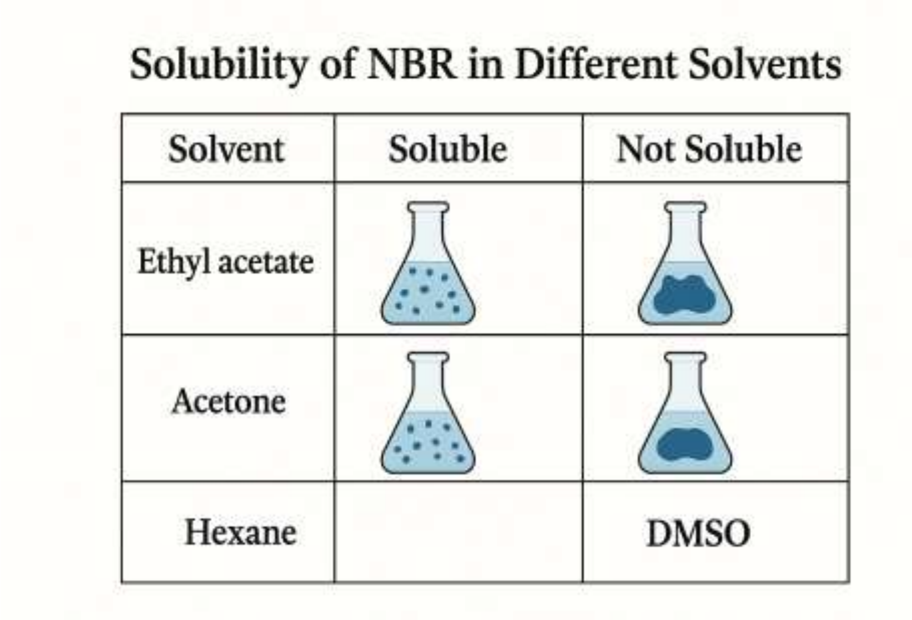
2.1 Materials

Four grades of NBR with varying acrylonitrile content (18%, 28.3%, 33.15%, and 38.15%) were procured in powdered form. Analytical grade solvents ethyl acetate, acetone, methyl ethyl ketone (MEK), hexane, and dimethyl sulfoxide (DMSO) were obtained from Merck and used without further purification.

2.2 Solubility Test Procedure

An accurately weighed 10 g sample of ground NBR was transferred into a clean, dry beaker. Subsequently, 90 mL of solvent was added, and the mixture was manually stirred to ensure uniform wetting. Following an initial soaking period of 30 minutes, the dispersion was subjected to continuous stirring while being placed in a hot-air oven maintained at 45 °C for 1–2 hours. Stirring was continued until either complete dissolution was achieved or phase separation was observed.

The solutions were visually inspected at regular intervals to assess dissolution, clarity, and any signs of phase separation or precipitation. Based on visual observations, solubility behavior was categorized as **soluble** (complete dissolution with stable solution) or **insoluble** (no dissolution or precipitation).



2.3 Glass Transition Temperature Measurement

For samples that achieved solubility (ethyl acetate, acetone, and MEK), Tg was determined using differential scanning calorimetry (DSC, TA Instruments Q2000). Approximately 5–8 mg of the polymer–

solvent sample was hermetically sealed in aluminum pans. Measurements were performed under nitrogen atmosphere at a heating rate of 10 °C/min, with temperature range −120 °C to +50 °C. Tg was determined from the midpoint of the heat capacity change during the second heating cycle.

3. Results and Discussion

3.1 Solubility Behavior

NBR displayed distinct solubility characteristics across solvents of varying polarity. Complete solubility was observed in ethyl acetate, acetone, and MEK, while insolubility persisted in hexane and DMSO. This trend can be explained using Hansen solubility parameters (δD, δP, δH).

- **Ethyl acetate, acetone, MEK:** These solvents have intermediate polarity and favourable dispersion and polar interactions that match with NBR's HSP range, enabling dissolution.
- **Hexane:** Being nonpolar, hexane has negligible polar or hydrogen-bonding interactions, making it incompatible with the polar nitrile groups of NBR.
- **DMSO:** Despite being polar, DMSO's high hydrogen bonding capability results in excessive polymer solvent interaction mismatch, leading to insolubility.

This indicates that an optimum balance of polarity not extreme values favours NBR solubility. Similar results were previously reported by Oertel et al. [19] and Hansen [20].

3.2 Glass Transition Temperature (Tg)

Table 1 summarizes Tg values of NBR in soluble solvents.

Table 1. Glass Transition Temperature (°C) of NBR in Selected Solvent

Solvent	ACN 18%	ACN 28%	ACN 33%	ACN 38%
Ethyl acetate	−52.83	−36.71	−31.85	−46.48
Acetone	−61.03	−47.74	−45.68	−32.00
MEK	−92.61	−82.23	−76.00	−65.00

Key Observations:

- Tg increased systematically with higher ACN content, consistent with reduced chain flexibility due to polar nitrile groups.
- Among solvents, MEK consistently produced the lowest Tg values, indicating strong plasticization effect.
- Ethyl acetate and acetone produced moderate Tg depression, consistent with partial polymer–solvent compatibility.
- Anomalies (e.g., slightly lower Tg at 38% ACN in ethyl acetate) may be attributed to microphase separation or incomplete interaction.

These results align with earlier studies on solvent polymer plasticization effects [21–22]. The findings also corroborate that solvent compatibility not only dictates solubility but also significantly modifies chain dynamics.

3.3 Industrial Relevance

Understanding solubility and Tg behavior provides valuable guidance for industrial processing. For example:

- **Adhesives and coatings:** MEK and acetone are favorable solvents due to good solubility and strong Tg reduction, promoting flexible films.
- **Fuel-resistant applications:** High ACN content NBR dissolved in ethyl acetate can yield robust coatings with high polarity resistance.
- **Rubber compounding:** Knowledge of solvent–polymer interactions assist in selecting processing aids and improving blend uniformity.

4. Conclusion

This study systematically analyzed the solubility and Tg behavior of NBR with varying ACN content (18.00%, 28.3%, 33.15%, and 38.15%) in five solvents. NBR dissolved readily in ethyl acetate, acetone, and MEK, while remaining insoluble in hexane and DMSO, highlighting the importance of solvent polarity balance. Tg measurements confirmed that increasing ACN content elevates Tg, whereas compatible solvents such as MEK produce significant plasticization effects.

The findings underscore the role of ACN content and solvent selection in tailoring NBR performance for industrial applications. This work provides a reference framework for industries engaged in adhesives, coatings, and specialty rubber processing.

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