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ON πgb*-CLOSED SETS IN TOPOLOGICAL SPACES

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Abstract: In this paper we introduced a new class of closed sets in a topological space called π- generalized b*-closed sets (briefly πgb*-closed sets) and some of its characteristics are investigated. Further we studied the concepts of πgb*-open sets and πgb*- $T_{1/2}$ space.

Keywords: πgb*-closed, πgb*- $T_{1/2}$ space, πgb*-open, πgb*-closure operator.

I. INTRODUCTION

Levine [4] and Andrijevic [1] introduced the concept of generalized open sets and b-open sets respectively in topological spaces. The class of b-open sets is contained in the class of semipre-open sets and contains the class of semi-open and the class of pre-open sets. Since then several researches were done and the notion of generalized semi-closed, generalized pre-closed and generalized semipre-open sets were investigated in [2, 5, 10]. In 1968 Zaitsev [12] defined π-closed sets. Later Dontchev and Noiri [9] introduced the notion of πg-closed sets. Park [11] defined πgp-closed sets. Then Aslim, Caksu and Noiri [3] introduced the notion of πgs-closed sets. The idea of πgb-closed sets were introduced by D.Sreeja and S.Janaki [7]. Later the properties and characteristics of πgb-closed sets were introduced by Sinem Caglar and Gulhan Ashim [6].
The aim of this paper is to investigate the notion of πgb*-closed sets and its properties. In section 3 we study the basic properties of πgb*-closed sets. In section 4 some characteristics of πgb*-closed sets are introduced and the idea of πgb*-$T_{1/2}$ space is discussed.

II. PRELIMINARY

Throughout this paper (X, τ) represent non-empty topological spaces on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a space (X, τ), cl(A) and int(A) denote the closure of A and the interior of A respectively. (X, τ) will be replaced by X if there is no chance of confusion.

Definition 2.1 Let (X, τ) be a topological space. A subset A of (X, τ) is called

(1) **a semi-closed set** [18] if $int(cl(A)) \subseteq A$

(2) **a α-closed set** [19] if $cl(int(cl(A))) \subseteq A$

(3) **a pre-closed set** [16] if $cl(int(A)) \subseteq A$

(4) **a semipre-closed set** [20] if $int(cl(int(A))) \subseteq A$

(5) **a regular closed set** [21] if $A = cl(int(A))$

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(6) **a b-closed set** [1] if cl(int(A)) ∩ int(cl(A)) ⊆ A.

(7) **a b*-closed** [13]set if int(cl(A)) ⊂ U, whenever A ⊂ U and U is b-open.

The complements of the above mentioned sets are called semi open, α-open, pre-open, semipre-open, regular open, b-open and b*-open sets respectively. The intersection of all semi closed (resp. α-closed, pre-closed, semipre-closed, regular closed and b- closed) subsets of (X, τ) containing A is called the semi closure (resp. α-closure, pre-closure, semipre-closure, regular closure and b-closure) of A and is denoted by scl(A) (resp. αcl(A), pcl(A), spcl(A), rcl(A) and bcl(A)). A subset A of (X,τ) is called clopen if it is both open and closed in (X, τ).

Definition 2.2

A subset A of a space (X,τ) is called ***π*-closed** [12] if A is a finite intersection of regular closed sets.

Definition 2.3

A subset A of a space (X,τ) is called

(1) **a g-closed set**[4] if cl(A) ⊂ U whenever A ⊂ U and U is open in (X, τ).
(2) **a gp-closed set [**5] if pcl(A) ⊂ U whenever A ⊂ U and U is open in (X, τ).
(3) **a gs-closed set** [10] if scl(A) ⊂ U whenever A ⊂ U and U is open in (X, τ).
(4) **a gb-closed set** [1] if bcl(A) ⊂ U whenever A ⊂ U and U is open in (X, τ).
(5) **a gα-closed set** [17] if αcl(A) ⊂ U whenever A ⊂ U and U is open in (X, τ).
(6) **a πg-closed set** [9] if cl(A) ⊂ U whenever A ⊂ U and U is π-open in (X, τ).
(7) **a πgα-closed set** [15] if αcl(A) ⊂ U whenever A ⊂ U and U is π-open in (X, τ).
(8) **a πgp-closed set** [11] if pcl(A) ⊂ U whenever A ⊂ U and U is π-open in (X, τ).
(9) **a πgs-closed set** [3]) if scl(A) ⊂ U whenever A ⊂ U and U is π-open in (X, τ).
(10) **a πgb-closed set** [7] if bcl(A) ⊂ U whenever A ⊂ U and U is π-open in (X, τ).

Complement of π-closed set is called **π-open set.**
Complement of g-closed, gp-closed, gs-closed, gb-closed, gα-closed, πgα-closed, πgp-closed, πgs-closed, πgsp-closed and πgb-closed sets are called g-open, gp-open, gs-open, gb-open, gα-open, πgα-open**,** πgp-open**,** πgs-open**,** πgsp-open and πgb-open sets respectively.

Definition 2.4

Let (X, τ) be a topological space then a set A ⊆ (X, τ) is said to be **Q-set** [8] if int(cl(A)) = cl(int(A)).

III. πgb*-CLOSED SETS IN TOPOLOGICAL SPACE

Definition 3.1

A subset A of a space (X, τ) is called **a πgb*-closed set** if int(bcl(A)) ⊂ U whenever A ⊂ U and U is π-open in (X, τ).

Theorem 3.1

Every closed set is πgb*-closed.

Proof

Let A be a closed set of (X, τ) such that A ⊆ U and U is π-open in X. Since bcl(A) ⊂ cl(A) = A, int(bcl(A)) ⊂ int(A) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.1

The converse of the above theorem is not true as seen from the following example.

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Example 3.1

Let X = {a, b, c}, and τ = { φ , {a} , {a, b} , {a, c} , X }. Here A = {a} is πgb*-closed but it is not closed.

Theorem 3.2

Every semi-closed set is πgb*-closed.

Proof

Let A be a semi-closed set of (X, τ) such that A ⊆ U and U is π-open in X. Since bcl(A) ⊂ scl(A) = A, int(bcl(A)) ⊂ int(A) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.2

The converse of the above theorem is not true as seen from the following example.

Example 3.2

Let X = {a, b, c} and τ = { φ , {b} , {c} , {a, b} , {b, c} , X }. Let A = {b,c}. Then A is πgb*-closed but it is not semi-closed.

Theorem 3.3

Every pre-closed set is πgb*-closed.

Proof

Let A be a pre-closed set of (X, τ) such that A ⊆ U and U is π -open in X. Since bcl(A) ⊂ pcl(A) = A, int(bcl(A)) ⊂ int(A) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.3

The converse of the above theorem is not true as seen from the following example.

Example 3.3

Let X = { a, b, c } and τ = { φ , {a} , {b} , {a, b} , {a, c} , X }. Let A = {a,b}. Then A is πgb*-closed but it is not pre-closed.

Theorem 3.4

Every α-closed set is πgb*-closed.

Proof

Let A be a α-closed set of (X, τ) such that A ⊆ U and U is π-open in X. Since bcl(A) ⊂ αcl(A) = A, int(bcl(A)) ⊂ int(A) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.4

The converse of the above theorem is not true as seen from the following example.

Example 3.4

Let X = {a, b, c} and τ = { φ , {a} , {a, c} , X }. Let A = {a,c}. Then A is πgb*-closed but it is not α-closed.

Theorem 3.5

Every b-closed set is πgb*-closed.

Proof

Let A be a b-closed subset of (X, τ) such that A ⊆ U and U is π-open in X. Since bcl(A) = A, int(bcl(A)) = int(A) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.5

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Example 3.5

Let X = {a, b, c, d} with topology τ = { φ , {a} , {b} ,{a, b} , {a, b, c} ,{a, b, d} ,X }. Let A = {a, b, c}. Then A is πgb*-closed but it is not b-closed.

Theorem 3.6

Every g-closed set is πgb*-closed.

Proof

Let A be a g-closed subset of (X, τ) such that A ⊆ U and U is π-open in X. Since every π-open set is open, cl(A) ⊂ U. As bcl(A) ⊂ cl(A) ⊂ U, int(bcl(A)) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.6

The converse of the above theorem is not true as seen from the following example.

Example 3.6

Let X = {a, b, c} and τ = { φ, {a, b}, X }. Let A = {a}. Then A is πgb*-closed but it is not g-closed.

Theorem 3.7

Every gp-closed set is πgb*-closed.

Proof

Let A be a gp-closed subset of (X, τ) such that A ⊆ U and U is π-open in X. Since every π-open set is open, pcl(A) ⊂ U. As bcl(A) ⊂ pcl(A) ⊂ U, int(bcl(A)) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.7

The converse of the above theorem is not true as seen from the following example.

Example 3.7

Let X = {a, b, c} and τ = {φ, {a, b}, X}. Let A = {a, b}. Then A is πgb*-closed but it is not gp-closed.

Theorem 3.8

Every gs-closed set is πgb*-closed.

Proof

Let A be a gs-closed subset of (X, τ) such that A ⊆ U and U is π-open in X. Since every π-open set is open, scl(A) ⊂ U. As bcl(A) ⊂ scl(A) ⊂ U, int(bcl(A)) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.8

The converse of the above theorem is not true as seen from the following example.

Example 3.8

Let X = {a, b, c} and τ = { φ , {a} , {a, b} , {a, c} , X }. Let A = {a, c}. Then A is πgb*-closed but it is not gs-closed.

Theorem 3.9

Every gα-closed set is πgb*-closed.

Proof

Let A be a gα-closed subset of (X, τ) such that A ⊆ U and U is π-open in X. Since every π-open set is open, αcl(A) ⊂ U. As bcl(A) ⊂ αcl(A) ⊂ U, int(bcl(A)) ⊆ int(U) = U. Hence A is πgb*-closed.

Remark 3.9

The converse of the above theorem is not true as seen from the following example.

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Example 3.9

Let X = {a, b} and τ = { φ , {a}, X }. Let A = {a}. Then A is πgb*-closed but it is not gα-closed.

Theorem 3.10

Every gb-closed set is πgb*-closed.

Proof

Let A be a gb-closed subset of (X,τ) such that A $\subseteq$ U and U is π-open in X. Since every π-open set is open, bcl(A) $\subset$ U. Thus int(bcl(A)) $\subseteq$ int(U) = U. Hence A is πgb*-closed.

Remark 3.10

The converse of the above theorem is not true as seen from the following example.

Example 3.10

Let X = {a, b, c} and τ = { φ , {a}, {a, c} , X }. Let A = {a,c}. Then A is πgb*-closed but it is not gb-closed.

Theorem 3.11

Every b*-closed set is πgb*-closed.

Proof

Let A be a b*-closed subset of (X,τ) such that A $\subseteq$ U and U is π-open in X. Since every π-open set is b-open and A is b*-closed, int(bcl(A)) $\subset$ U. Hence A is πgb*-closed.

Remark 3.11

The converse of the above theorem is not true as seen from the following example.

Example 3.11

Let X = {a, b, c} and τ = { φ , {a} , {a, b} , {a, c} , X }. Let A = {a}. Then A is πgb*-closed but it is not b*-closed.

Theorem 3.12

Every πg-closed set is πgb*-closed.

Proof

Let A be a πg-closed subset of (X,τ) such that A $\subseteq$ U and U is π-open in X. Then cl(A) $\subset$ U and as bcl(A) $\subset$ cl(A) $\subset$ U, int(bcl(A)) $\subseteq$ int(U) = U. Hence A is πgb*-closed.

Remark 3.12

The converse of the above theorem is not true as seen from the following example.

Example 3.12

Let X = {a, b, c, d} and τ = { φ , {a} , {d} , {a, d} , {c, d} , {a, c, d} , X }. Let A = {c}. Then A is πgb*-closed but it is not πg-closed.

Theorem 3.13

Every πgα-closed set is πgb*-closed.

Proof

Let A be a πgα-closed subset of (X,τ) such that A $\subseteq$ U and U is π-open in X. Then αcl(A) $\subset$ U and as bcl(A) $\subset$ αcl(A) $\subset$ U, int(bcl(A)) $\subseteq$ int(U) = U. Hence A is πgb*-closed.

Remark 3.13

The converse of the above theorem is not true as seen from the following example.

Example 3.13

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Let X = {a, b, c, d, e} and τ = { φ , {a, b} , {c, d} , {a, b, c, d} , X }. Let A = {a}. Then A is πgb*-closed but it is not πgα-closed.

Theorem 3.14

Every πgp-closed set is πgb*-closed.

Proof

Let A be a πgp-closed subset of (X, τ) such that A $\subseteq$ U and U is π-open in X. Then pcl(A) $\subset$ U and as bcl(A) $\subset$ pcl(A) $\subset$ U, int(bcl(A)) $\subseteq$ int(U) = U. Hence A is πgb*-closed.

Remark 3.14

The converse of the above theorem is not true as seen from the following example.

Example 3.14

Let X = {a, b, c, d, e} and τ = { φ , {a, b} , {c, d} , {a, b, c, d} , X }. Let A = {a, b}. Then A is πgb*-closed but it is not πgp-closed.

Theorem 3.15

Every πgs-closed set is πgb*-closed.

Proof

Let A be a πgs-closed subset of (X, τ)such that A $\subseteq$ U and U is π-open in X. Then scl(A) $\subset$ U and as bcl(A) $\subset$ scl(A) $\subset$ U, int(bcl(A)) $\subseteq$ int(U) = U. Hence A is πgb*-closed.

Remark 3. 15

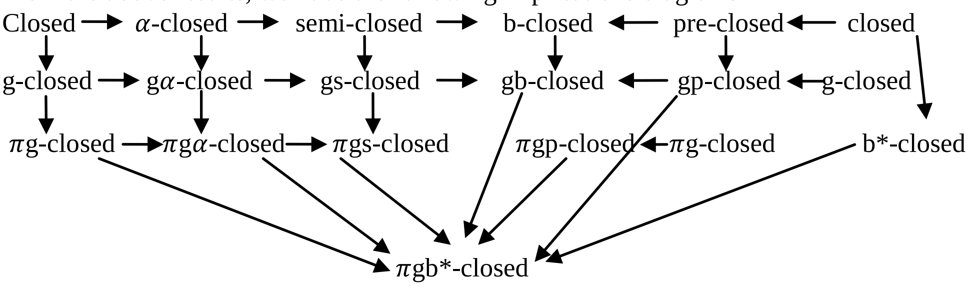
The converse of the above theorem is not true as seen from the following example.

Example 3.15

Let X be the real numbers with the usual topology and A be the set of irrational numbers in the interval (0, 2). Then A is πgb*-closed but it is not πgs-closed.

Remark 3.16

From the above results, we have the following implications diagram.



A ⟶ B means A implies B, but not conversely.

IV. CHARACTERISTICS OF πgb*-CLOSED SETS

Remark 4.1

Finite union of πgb*-closed sets need not be πgb*-closed which can be seen from the following example.

Example 4.1

Let X = { a, b, c } with topology τ = { φ , {b} , {c} , {b, c} , X }. Let A = {b} and B = {c} then both A and B are πgb*-closed. But, A ∪ B = {b, c} is not πgb*-closed.

Remark 4.2

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Finite intersection of πgb*-closed sets need not be πgb*-closed which can be seen from the following example.

Example 4.2

Let X = { a, b, c, d } with topology τ = { φ , {a} , {b} , {a, b, c} , {a, b} , {a, b, d} , X }. Let A = {a, b, c} and B = {a, b, d}. Then both A and B are πgb*-closed. But, A ∩ B = {a, b} is not πgb*-closed.

Theorem 4.1

Let (X, τ) be a topological space if A ⊂ X is πgb*-closed set then int(bcl(A)) – A does not contain any non empty π-closed set.

Proof

Let A be a πgb*-closed set in (X, τ) and F ⊂ int(bcl(A)) – A such that F is π-closed in X. Then (X – F) is π-open in X and A ⊆(X - F). Since A is πgb*-closed, int(bcl(A)) ⊂ (X - F) ⇒F⊂ (X - int(bcl(A)))
Therefore F ⊂ (int(bcl(A)) – A) ∩ (X - int(bcl(A))) ⇒ F = φ. Therefore int(bcl(A)) – A does not contain any non empty π-closed set.

Theorem 4.2

Let B ⊆ A ⊆ X where A is πgb*-closed and π-open in X, then B is πgb*-closed relative to A if and only if B is πgb*-closed in X.

Proof

Let B ⊆ A ⊆ X where A is a πgb*-closed and π-open set. Therefore int(bcl(A)) ⊆A. Since B ⊆ A, int(bcl(B)) ⊆ int(bcl(A)) ⊆A. Let B be πgb*-closed in A and let B ⊆ U where U is π-open in X, then B = B ∩ A ⊂ U ∩ A, which is π-open in A.Therefore $(int(bcl(B)))_A$ ⊂ U ∩ A. Also, $(int(bcl(B)))_A$ = (int(bcl(B))) ∩ A = (int(bcl(B))) .Thus (int(bcl(B))) ⊂ U ∩ A ⊂U. Hence B is πgb*-closed in X.
Conversely, let B be πgb*-closed in X. Let B ⊂ O where O is π-open in A. Then O = U ∩ A where U is π-open in X. Therefore B ⊂ O = U ∩ A ⊂U. Since B is πgb*-closed in X, int(bcl(B)) ⊂U. Hence $(int(bcl(B)))_A$ = A ∩ int(bcl(B)) ⊂ U ∩ A = O. Hence B is πgb*-closed relative to A.

Theorem 4.3

If A is a πgb*-closed and B is any set such that A ⊆ B ⊆ int(bcl(A)), then B is a πgb*-closed.

Proof

Let B ⊆U and U be π-open. Since A ⊆ B ⊆ U and A is πgb*-closed, int(bcl(A)) ⊆ U. Now int(bcl(B)) ⊆ int(bcl(A)) ⊆ U. Hence B is a πgb*-closed.

Theorem 4.4

Let (X, τ) be a topological space if A ⊂X is nowhere dense then A is πgb*-closed.

Proof

Let A⊆U where U is π-open in X. Since A is nowhere dense, int(cl(A)) = φ .Now int(bcl(A)) ⊆int(cl(A)) = φ ⊆U. Therefore A is πgb*-closed in X.

Theorem 4.5

In a topological space(X, τ) for each x ∈ X, X\ {x} is either πgb*-closed or π-open in X.

Proof

Suppose X\ {x} is not π-open then X is the only π-open set containing X\{x}. Hence int(bcl(X\{x})) ⊆ X ⇒ X\ {x} is πgb*-closed.

Definition 4.1

A set A ⊆X is called **πgb*-open** if its complement is πgb*-closed in X.

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Theorem 4.6

A subset A $\subseteq$X is πgb*-open if and only if F $\subseteq$cl(bint(A)) whenever F is π-closed and F$\subseteq$A.

Proof

Assume that A$\subseteq$X is πgb*-open. Let F be π-closed such that F$\subseteq$A. Then (X – A) $\subseteq$ (X – F). Since (X – A) is πgb*-closed and (X – F) is π-open, int(bcl(X – A)) $\subseteq$ (X– F) $\Rightarrow$ (X – cl(bint(A))) $\subseteq$ (X – F). Hence F$\subseteq$ cl(bint(A)). Conversely, assume that F is π-closed and F$\subseteq$A such that F$\subseteq$cl(bint(A)). Let (X – A) $\subseteq$U, where U is π-open. Then (X – U) $\subseteq$A and since (X – U) is π-closed, (X – U) $\subseteq$ cl(bint(A)) $\Rightarrow$ int(bcl(X–A)) $\subseteq$U. Hence (X – A) is πgb*-closed and A is πgb*-open.

Theorem 4.7

If cl(bint(A)) $\subseteq$ B $\subseteq$ A and A is πgb*-open, then B is πgb*-open.

Proof

Let F be a π-closed set such that F $\subseteq$B. since B $\subseteq$ A we get F $\subseteq$ A. Given A is πgb*-open thus F $\subseteq$ cl(bint(A)) $\subseteq$ cl(bint(B)) . Therefore B is πgb*-open.

Definition 4.2

A space (X,τ) is called a **πgb*-$T_{1/2}$ space** if every πgb*-closed set is b*-closed.

Theorem 4.8

For a topological space (X,τ) the following are equivalent

1) X is πgb*-$T_{1/2}$
2) $\forall$ subset A $\subseteq$ X, A is πgb*-open if and only if A is b*- open.

Proof

(1) $\Rightarrow$(2)

Let A $\subseteq$ X be πgb*-open. Then (X - A) is πgb*-closed and by (1) (X - A) is b*- closed $\Rightarrow$A is b*-open. Conversely assume A is b*-open. Then (X - A) is b*-closed. As every b*-closed set is πgb*-closed, (X - A) is πgb*-closed $\Rightarrow$A is πgb*-open.

(2)$\Rightarrow$ (1)

Let A be a πgb*-closed set in X. Then (X - A) is πgb*-open. Hence by (2) (X - A) is b*-open $\Rightarrow$A is b*-closed. Hence X is πgb*-$T_{1/2}$.

Theorem 4.9

Let (X,τ) be a πgb*-$T_{1/2}$ space then every singleton set is either π-closed or b*-open.

Proof

Let x $\in$ X suppose {x} is not π-closed. Then X – {x} is not π-open. Hence X – {x} is trivially πgb*-closed. Since X is πgb*-$T_{1/2}$ space, X – {x} is b*-closed $\Rightarrow${x} is b*-open.

Definition 4.3

The intersection of all πgb*-closed set containing A is called the **πgb*-closure of A** denoted by πgb*-cl(A).

Theorem 4.10

Let A $\subseteq(X,\tau)$ and x $\in$ X. Then x $\in$ πgb*-cl(A) if and only if V $\cap$ A $\neq \varphi$ for every πgb*- open set V containing x.

Proof

Suppose x $\in$ πgb*-cl(A) and let V be an πgb*-open set such that x $\in$ V. Assume V $\cap$ A = φ, then A $\subset$X\V $\Rightarrow$ πgb*-cl(A) $\subset$ X\V $\Rightarrow$ x $\in$ X\V , a contradiction. Thus V $\cap$ A $\neq \varphi$ for every πgb*-open set V containing x. To prove the converse suppose x $\notin\pi$gb*-cl(A) $\Rightarrow$ x $\in$ X \ πgb*-cl(A) = V (say). Then V is a πgb*-open and x $\in$ V. Also since A $\subseteq$ πgb*-cl(A) $\Rightarrow$A $\not\subset$ V$\Rightarrow$ V $\cap$ A = φ. Hence the theorem.

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Theorem 4.11

For a set A $\subseteq$ (X, τ) if A is π-clopen then A is π-open, Q-set, πgb*-closed set.

Proof

Let A be π-clopen. Then A is both π-open and π-closed. Hence A is both open and closed
Therefore, cl(int(A)) = int(cl(A)) , thus A is a Q-set.
As bcl (A) $\subseteq$ cl(A) = A . int(bcl (A)) $\subseteq$ int(A) = A.

V. CONCLUSION

The study of πgb*-closed set is derived from the definition of πgb-closed sets and b*-closed sets. This study can be extended to bitopological spaces and fuzzy topological spaces.

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