Adjuncts to `std::hash`

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Abstract

Inspired by Lippincott's paper [P0513R0] and subsequent correspondence with her, this paper proposes, for the standard library, a few templates of general use in connection with `std::hash`.

HASH, x. There is no definition for this word—nobody knows what hash is.
— Ambrose Bierce

He took the Who's feast,
he took the Who pudding, he took the roast beast.
He cleaned out that ice box as quick as a flash.
Why, the Grinch even took their last can of Who hash.
— Dr. Seuss (né Theodor Seuss Geisel)

1 Introduction

Lippincott's paper [P0513R0], adopted[1] for C++17 in Issaquah, introduced new vocabulary to describe specializations of `std::hash`. Each is now "either *disabled* ('poisoned') or *enabled* ('untainted')."[2]

The paper also suggested "a standard trait `hash_enabled<T>`." No such trait was formally proposed, however, because WG21 was at the time focussed on ballot resolution and other C++17 preparations.

To remedy that lack, this paper proposes that trait (under a slightly different name, however). It also proposes a few other adjuncts that seem generally useful to `std::hash` users.

[1] Addressing the following issues and National Body comments: LWG 2543, FI 15, GB 69, and LWG 2791.

[2] While it is possible to code a `hash` specialization that is neither enabled nor disabled, such a specialization does not meet the `std::hash` requirements. See §4 for details.

2 Proposals

2.1 is_enabled_hash[3]

The requirements for an enabled **std::hash** specialization are specified in [unord.hash]/4. We propose a corresponding new trait, **is_enabled_hash**, to decide at compile time whether a given specialization meets those specifications.

The following expository implementation illustrates the trait's proposed semantics:

```
template< typename H >
struct is_enabled_hash : false_type { };

template< typename T >
  requires is_default_constructible_v<hash<T>>
       and is_copy_constructible_v   <hash<T>>
       and is_move_constructible_v   <hash<T>>
       and is_copy_assignable_v      <hash<T>>
       and is_move_assignable_v      <hash<T>>
       and is_destructible_v         <hash<T>>
       and is_swappable_v            <hash<T>>
       and is_callable_v             <hash<T>(T)>
       and is_same_v<size_t, decltype(hash<T>(declval<T       >()))>
       and is_same_v<size_t, decltype(hash<T>(declval<T      &>()))>
       and is_same_v<size_t, decltype(hash<T>(declval<T const&>()))>
struct
  is_enabled_hash< hash<T> > : true_type { };

template< typename H >
constexpr bool is_enabled_hash_v = is_enabled_hash<H>::value;
```

As part of this proposal, user specialization of this template is not permitted, just as is the case for nearly all type traits.

2.2 hash_for and is_hashable

Upon reviewing and approving a draft of the above-proposed trait, Lippincott commented:[4]

> Also, the question I imagine most people will want answered is "Can I hash **T**?" rather than "Is **H** an enabled hasher?" I'd like to add **is_hashable** as a shortcut . . .

The following expository implementation, a slight expansion of Lippincott's code, illustrates the intended semantics of this proposed "shortcut":

```
template< typename T >  // exposition only
using remove_cv_ref_t = remove_cv_t< remove_reference_t<T> >;

template< class T >
using hash_for = hash< remove_cv_ref_t<T> >;

template< class T >
using is_hashable = is_enabled_hash< hash_for<T> >;

template< class T >
constexpr bool is_hashable_v = is_hashable<T>::value;
```

[3] See §4 for alternative designs.

[4] Lisa Lippincott: "Re: Follow-up to P0513R0." Personal correspondence, 2016–12–09.

2.3 `hash_value`

Finally, Lippincott suggested:[5]

> And if it's not there already, we could use a function for calculating hashes. Making every user instantiate, construct, and call the right specialization is for the birds.

The following expository implementation is adapted from Lippincott's code; user specialization of this template, too, is not permitted. By design, attempted instantiation of this template for a type without an enabled hash yields an ill-formed program:

```
template< class T >
  requires is_hashable_v<T>
size_t
  hash_value( T&& t )
  noexcept( noexcept(hash_for<T>{}(std::forward<T>(t))) )
{
  return hash_for<T>{}( std::forward<T>(t) );
}
```

Note that this proposed template shares its name with a seemingly-similar Boost facility. However, the corresponding Boost documentation states[6], in pertinent part:

- "Generally shouldn't be called directly by users . . . ."
- "This hash function is not intended for general use, and isn't guaranteed to be equal during separate runs of a program . . . ."

The version proposed herein has no such design restrictions.

2.4 `is_nothrow_hashable`

Recent adoption of [P0599R1] has emphasized the **`noexcept`** nature of most of the library-provided **`hash`** specializations. Because this status may be of special interest in the case of **`operator()`**, we propose a corresponding **`is_nothrow_hashable`** trait:

```
template< class T >
constexpr bool is_nothrow_hashable_v = is_hashable_v<T>
  and noexcept(hash_value(declval<T>()));

template< class T >
using is_nothrow_hashable = bool_constant< is_nothrow_hashable_v >;
```

3 Proposed wording[7]

3.1 Insert into the synopsis in [function.objects] as shown.

[5] *Ibid.*

[6] See http://www.boost.org/doc/libs/1_63_0/doc/html/hash/reference.html#boost.hash_value_idp743313104.

[7] All proposed additions (there are no ~~deletions~~) are relative to the post-Kona Working Draft [N4687]. Editorial notes are displayed against a gray background.

```
namespace std {
  ...
  // 23.14.15, hash function primary template and adjuncts
  template<class T> struct hash;
  template<class H> struct is_enabled_hash;
  template<class H>
    constexpr bool is_enabled_hash_v = is_enabled_hash<H>::value;
  template<class T> using hash_for = hash<see below>;
  template<class T> using is_hashable = is_enabled_hash<hash_for<T»;
  template<class T>
    constexpr bool is_hashable_v = is_hashable<T>::value;
  template<class T> size_t hash_value(T&& t) noexcept(see below);
  template<class T>
    constexpr bool is_nothrow_hashable_v = is_hashable_v<T>
    and noexcept(hash_value(declval<T>()));
  template<class T>
    using is_nothrow_hashable = bool_constant<is_nothrow_hashable_v>;
  ...
}
```

3.2 Retitle [unord.hash] as shown. (Note that there is a pre-existing discrepancy between this title and the corresponding entry in the synopsis (see above); we recommend that the Project Editor determine whether and how this mismatch should be resolved.)

23.14.15 Class template **`hash`** and adjuncts [unord.hash]

3.3 Append the following new text to the retitled [unord.hash].

`template<class H> struct is_enabled_hash;`

6 *Remarks:* All specializations of this template shall meet the UnaryTypeTrait requirements ([meta.rqmts]) with a BaseCharacteristic of **`true_type`** if **`H`** is an enabled specialization of **`hash`** ([unord.hash]) and a BaseCharacteristic of **`false_type`** otherwise. [*Note:* The latter does not necessarily imply that **`H`** is a disabled specialization of **`hash`**. — *end note*] The behavior of a program that adds specializations for this template is undefined.

`template<class T> using hash_for = hash<`*see below*`>;`

7 *Remarks:* The template argument to **`hash`** shall correspond to **`remove_cv_t<remove_reference_t<T>>`**.

`template<class T> size_t hash_value(T&& t) noexcept(`*see below*`);`

8 The expression inside **`noexcept`** is equivalent to:
`noexcept(hash_for<T>{}(std::forward<T>(t)))`.

9 *Requires:* Participates in overload resolution only if **`is_hashable_v<T>`** is **`true`**.

10 *Effects:* Equivalent to: **`return hash_for<T>{}(std::forward<T>(t));`**

11 *Remarks:* The behavior of a program that adds specializations for this template is undefined.

4 Alternatives

As we cited in §1, it is convenient to think of **`std::hash`** specializations as "either *disabled* ('poisoned') or *enabled* ('untainted')." However, it is technically possible to code a specialization that meets neither definition. Of course, a program with such a specialization runs afoul of [namespace.std]:

> 1 . . . . A program may add a template specialization for any standard library template to namespace **`std`** only if . . . the specialization meets the standard library requirements for the original template . . . .

To what lengths, if any, should the standard library go to diagnose such undefined behavior?

1. In particular, should we respecify the proposed **`is_enabled_hash`** trait as follows?
   - Have a BaseCharacteristic of **`true_type`** if template parameter **`H`** is an enabled specialization of **`hash`**;
   - have a BaseCharacteristic of **`false_type`** if **`H`** is a disabled specialization of **`hash`**; and
   - be ill-formed[8], otherwise.
2. Alternatively, instead of altering the **`is_enabled_hash`** specification, should we provide, in addition, an **`is_disabled_hash`** trait, specified as follows?
   - Have a BaseCharacteristic of **`true_type`** if template parameter **`H`** is a disabled specialization of **`hash`**;
   - have a BaseCharacteristic of **`false_type`**, otherwise.

5 Acknowledgments

Special thanks to Lisa Lippincott, who inspired essentially all of this proposed functionality. Thanks also to Andrey Semashev and the other readers of this paper's pre-publication drafts for their thoughtful comments.

6 Bibliography

[N4659] Richard Smith: "Working Draft, Standard for Programming Language C++." ISO/IEC JTC1/SC22/WG21 document N4659 (post-Kona mailing), 2017–03–21. http://wg21.link/n4659.

[N4687] Richard Smith: "Working Draft, Standard for Programming Language C++." ISO/IEC JTC1/SC22/WG21 document N4687 (post-Toronto mailing), 2017–07–30. http://wg21.link/n4687.

[P0513R0] Lisa Lippincott: "Poisoning the Hash." ISO/IEC JTC1/SC22/WG21 document P0513R0 (post-Issaquah mailing), 2016–11–10. http://wg21.link/p0513r0.

[P0599R1] Nicolai Josuttis: "**`noexcept`** for Hash Functions." ISO/IEC JTC1/SC22/WG21 document P0599R1 (post-Kona mailing), 2017–03–02. http://wg21.link/p0599R1.

[8] This can be implemented via a judiciously-placed **`static_assert`**, for example.

7 Document history

Version	Date	Changes
0	2017-02-01	• Published as P0549R0, pre-Kona.
1	2017-06-11	• Added **`is_nothrow_hashable`** (§2.4, etc.). • Updated relative to the post-Kona Working Draft [N4659]. • Made minor editorial improvements. • Published as P0549R1, pre-Toronto.
2	2017-10-10	• Updated relative to the post-Toronto Working Draft [N4687]. • Revised citations to use wg21.link. • Made minor technical and editorial improvements. • Published as P0549R2, pre-Albuquerque.