

## Topic 6A: Standard Model of Particle Physics

### Skill 47 – Relating Particles to the Fundamental Forces (Using the Standard Model Charts)

1. ANTI-PARTICLES have the same mass but opposite charge to particles.
2. The symbol for the up quark is u

The symbol for the anti-up quark is  $\bar{u}$

3. Complete the chart for each of the following particles:

	Particle category	Charge	Composition (quarks composition/charge)	
Proton	baryon (hadron)	+1	uud	$\frac{2}{3}, \frac{2}{3}, -\frac{1}{3}$
Neutron	baryon (hadron)	0	udd	$\frac{2}{3}, \frac{1}{3}, -\frac{1}{3}$
Electron	lepton	-1	—	-1e

4. Fill-in the blanks

Quarks have a partial charge of  $\frac{2}{3}$  or  $-\frac{1}{3}$  but combine to form elementary particles such as protons and neutrons.

The other common elementary particle is the electron which is a lepton and NOT made of quarks.

For every particle there exists a corresponding antiparticle which contains the same mass and structure but opposite electric charge. An anti-particle is symbolized by a line over the letter for the particle. For example the symbol for the up quark is u so the anti-up quark is symbolized by  $\bar{u}$ . A proton is made of uud quarks so an anti-proton is made of  $\bar{u}\bar{u}\bar{d}$ .

Sub atomic particles such as the electron, proton and neutron are the smallest independent particle that can exist, they are called the elementary particles.

Quarks are not elementary particles because they have partial (fractional) charge.

Quarks must be combined to form a zero charge or whole number charge.

A proton is composed of "uud" and has a charge of +1; an antiproton is composed of  $\bar{u}\bar{u}\bar{d}$  with a charge of -1. A neutron is composed of udd with a charge of 0; an anti-neutron is composed of  $\bar{u}\bar{d}\bar{d}$  with a charge of 0. (A neutron is its own anti-particle).

An elementary particle with a charge of  $1e$  has a charge in coulombs of  $1.6 \times 10^{-19} \text{C}$ . To convert ~~by~~ elementary charge to coulombs multiply by  $1.6 \times 10^{-19} \text{C}$ .

USE THE FLOW CHART ON THE PHYSICS REFERENCE TABLE TO GROUP PARTICLES ACCORDING TO COMPOSITION OF QUARKS AND LEPTONS

5. Classify each of the following particles as a quark, lepton, anti-lepton, baryon, and anti-baryon or meson

- udd baryon
- Electron lepton
- $t\bar{t}$  energy (due)
- $u\bar{u}\bar{d}$  anti-baryon
- s quark
- anti-neutrino anti-lepton
- css baryon
- $u\bar{d}$  meson

6. Determine the charge on each of the following particles

- $t\bar{t}b$   $\frac{2}{3}, \frac{2}{3}, -\frac{1}{3} = +1$
- uts  $\frac{2}{3}, \frac{2}{3}, -\frac{1}{3} = 1$
- uuu  $\frac{2}{3} + \frac{2}{3} + \frac{2}{3} = 2$
- $u\bar{u}$  0  $\Rightarrow$  energy
- ddb  $-\frac{1}{3} - \frac{1}{3} - \frac{1}{3} = -1$
- $b\bar{t}$   $-\frac{1}{3} + \frac{2}{3} = \frac{1}{3}$

7. Give two examples of baryons that add up to a charge of +1

uud      ttb

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8. Which particles are *not* affected by the strong force?  $\rightarrow$  made up of quarks

- A) hadrons      B) protons  
C) neutrons      D) electrons  $\rightarrow$  leptons

9. The particles in a nucleus are held together primarily by the

- A) strong force  
B) gravitational force  
C) electrostatic force  
D) magnetic force

Base your answers to questions 10 and 11 on the table below, which shows data about various subatomic particles.

**Subatomic Particle Table**

Symbol	Name	Quark Content	Electric Charge	Mass (GeV/c <sup>2</sup> )
p	proton	uud	+1	0.938
$\bar{p}$	antiproton	$\bar{u}\bar{u}\bar{d}$	-1	0.938
n	neutron	udd	0	0.940
$\Lambda$	lambda	uds	0	1.116
$\Omega^-$	omega	sss	-1	1.672

10. All the particles listed on the table are classified as

- A) mesons      B) hadrons      C) antimatter      D) leptons  
*quark anti-quark*      *3 quarks*      *no quarks*

11. Which particle listed on the table has the opposite charge of, and is more massive than, a proton?

- A) antiproton      B) neutron      C) lambda      D) omega  
*same mass*      *more mass*      *no mass*      *more mass*

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12. Baryons may have charges of

- A)  $+1e$  and  $+\frac{4}{3}e$     B)  $+2e$  and  $+3e$   
 C)  $-1e$  and  $+1e$     D)  $-2e$  and  $-\frac{2}{3}e$

13. What is the total number of quarks in a helium nucleus consisting of 2 protons and 2 neutrons?

- A) 16    B) 12    C) 8    D) 4

*4 baryons @ 3 quarks each = 12 quarks*

14. What fundamental force holds quarks together to form particles such as protons and neutrons?

- A) electromagnetic force  
 B) gravitational force  
 C) strong force  
 D) weak force

15. A top quark has an approximate charge of

- A)  $-1.07 \times 10^{-19} \text{ C}$     B)  $-2.40 \times 10^{-19} \text{ C}$   
 C)  $+1.07 \times 10^{-19} \text{ C}$     D)  $+2.40 \times 10^{-19} \text{ C}$

$$+\frac{2}{3}e \times \frac{1.6 \times 10^{-19} \text{ C}}{e} =$$

16. According to the Standard Model of Particle Physics, a meson is composed of

- A) a quark and a muon neutrino  
 B) a quark and an antiquark  
 C) three quarks  
 D) a lepton and an antilepton

17. What are the sign and charge, in coulombs, of an antiproton?  $-1e$

18. The tau neutrino, the muon neutrino, and the electron neutrino are all

- A) leptons    B) hadrons  
 C) baryons    D) mesons

19. A meson may not have a charge of

- A)  $+1e$     B)  $+2e$     C)  $0e$     D)  $-1e$

20. Protons and neutrons are examples of

- A) positrons    B) baryons  
 C) mesons    D) quarks

21. Compared to the mass and charge of a proton, an antiproton has

- A) the same mass and the same charge  
 B) greater mass and the same charge  
 C) the same mass and the opposite charge  
 D) greater mass and the opposite charge

22. A particle that is composed of two up quarks and one down quark is a

- A) meson    B) neutron  
 C) proton    D) positron

$$uud = \left(\frac{2}{3}\right) + \left(\frac{2}{3}\right) + \left(-\frac{1}{3}\right) = 1$$

23. A particle unaffected by an electric field could have a quark composition of

- A)  $css$     B)  $bbb$     C)  $udc$     D)  $uud$   
*Handwritten calculations: A)  $\frac{2}{3} - \frac{1}{3} - \frac{1}{3} = 0$ ; B)  $3(\frac{2}{3}) = +2$ ; C)  $\frac{2}{3} - \frac{1}{3} + \frac{2}{3} = +1$ ; D)  $\frac{2}{3} + \frac{2}{3} + \frac{1}{3} = +1$*

24. A baryon may have a charge of

- A)  $-1/3 e$     B)  $0 e$   
 C)  $+2/3 e$     D)  $+4/3 e$

25. A particle is known to only contain down and strange quarks, what can be its charge?

- A)  $+2 e$     B)  $+1 e$     C)  $0 e$     D)  $-1 e$

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26. Which of the following is the boson (force carrier) of the electromagnetic force

- A) photon
- B) graviton
- C) electron
- D) quark

27. Which of the following pair interactions will result in annihilation

- A) a charm quark and anti bottom quark
- B) a charm quark and top quark
- C) a charm quark and anti-charm quark
- D) a top quark and a bottom quark

particle &  
corresponding  
anti-particle

